Issued January 29, 1907.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—BULLETIN No. 92.

A. D. MELVIN, CHIEF OF BUREAU.

THE MILKING MACHINE AS A FACTOR IN DAIRYING.

(A PRELIMINARY REPORT.)

I.—PRACTICAL STUDIES OF A MILKING MACHINE.

BY

C. B. LANE, B. S.,

Assistant Chief, Dairy Division, Bureau of Animal Industry.

II.—BACTERIOLOGICAL STUDIES OF A MILKING MACHINE.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., October 13, 1906.

Sir: I have the honor to transmit herewith a preliminary report on "The Milking Machine as a Factor in Dairying," an investigation of this subject by the Dairy Division having been authorized by you. The first part deals with the practical side and the second part with the bacteriological phase of the subject.

Recent improvements in milking machines have led to their introduction and practical use in some of the larger dairies of the country, and there are indications that these machines may come into general use in the near future and become an important economic factor in the dairy industry. While the investigations so far made have been too limited to justify any sweeping deductions or positive conclusions, it is believed, in view of the importance and present interest of the subject to dairymen, that the results here presented are of sufficient value to warrant their publication, and I therefore recommend the publication of this report as Bulletin No. 92 in the series of this Bureau. The investigations will be continued and further results may be reported later.

The experimental work which is the basis of this bulletin was conducted in August, 1905, but owing to unavoidable delays the manuscript has not been ready for publication until now.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

I.—PRACTICAL STUDIES OF A MILKING MACHINE.

II.—BACTERIOLOGICAL STUDIES OF A MILKING MACHINE.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

THE MILKING MACHINE AS A FACTOR IN DAIRYING.

I.—PRACTICAL STUDIES OF A MILKING MACHINE.

By C. B. Lane, B. S.
Assistant Chief, Dairy Division, Bureau of Animal Industry.

INTRODUCTION.

For more than a quarter of a century machinery has been successfully used in separating the cream from the milk and churning it into butter, but a machine for milking the cows has been more difficult to supply. It has long been realized that a successful and practical cow milker would mean a profitable revolution of the dairy industry, as it would render the work of milking much easier and reduce the necessity for hired help, thus making the dairyman more independent. Efforts have been made by scores of inventors for more than half a century to construct a machine that would milk cows in a satisfactory manner and without injury. The German writer Martiny states that 29 different milking machines known to him had been patented in different countries or mentioned in the dairy literature between the years 1877 and 1898.

The annual reports of the United States Commissioner of Patents show that during the period of 34 years from 1872 to 1905, inclusive, 127 patents were taken out in this country alone for milking machines or separate parts of them. A number of machines have been successful in extracting the milk from the cow by either pressure or suction, or by the two combined, but have fallen short of being practical in some vital point. Naturally, inventors have attempted to imitate the way in which the calf sucks its dam. The difficulty has been to reproduce the peculiar influence which the sucking calf has upon the cow and to devise a machine which will not irritate the animal and which will do its work without injury. Another difficulty in devising a cow milker has been to construct it so that it could be adjusted to all cows. Individual animals vary greatly in the size and conformation of their udders, and even the same cow varies somewhat in the size and shape of her udder and teats during the different stages of her

lactation period. Cows also vary greatly in disposition and temperament. A successful cow milker, therefore, must meet all these different conditions. Since milking must necessarily be an artificial process, it has been thought for some time that animals would become accustomed to being milked by machinery just the same as they become accustomed to hand milking, provided a milking machine could be perfected that would be comfortable to the animal when in operation. A heifer, for example, coming into milk the first time would take as readily to one artificial method as to another, other things being equal.

While no milking machine yet invented has shown its practical value in a way that has led to its general use, recent improvements in machines of this type have resulted in greater simplicity of construction and effectiveness in operation, and consequently they are in practical use in a limited number of the larger dairies. Indeed, the prospect for the general introduction of milking machines appears to be so favorable that it was thought advisable by the Secretary of Agriculture to authorize an investigation of the fundamental problems involved in the use of such machines. These fundamental problems may be stated as follows: (1) The practicability of substituting machine for hand milking in the actual operations of dairying; (2) the effects of machine milking on the quantity and composition of the milk yielded by the cows; (3) the effects of machine milking on the cleanliness, sanitary character, and keeping qualities of the milk.

In making such an investigation it was, of course, necessary to select some machine for use. The machine selected is one which was found to be in actual use in a number of dairies, and one which appeared to offer adequate means for conducting the proposed investigation. Its selection was not intended as in any sense a recommendation of this particular machine to the favor of dairymen. It is believed, however, that, in so far as the investigation has demonstrated the merits of this machine, it will benefit all inventors and manufacturers of successful milking machines.

The authors fully appreciate the fact that these investigations have been too limited to justify any sweeping deductions or positive conclusions. But in view of the probable general introduction of such machinery in the near future, it is believed the results of the investigations are of sufficient value to justify their publication.

SOME MILKING MACHINES IN USE.

As a complete account is hereinafter given of the machine used in the investigation, a brief description will suffice for the other machines presented here, none of which were used in this investigation, and in regard to the efficiency of which no opinion can consequently be exprest.

A FOOT-POWER MILKER.

This machine (pl. 1) is designed for use in small herds and has no stationary fixtures. It consists of a suction pump worked by foot power, 2 pieces of rubber hose, and 8 suction cups to be attached to the teats of the 2 cows, which can be milked at the same time. The milk passes thru the cylinder, and also thru the valve in the pump piston itself. The operator sits between the 2 cows and works the pump with his feet. On opening the spigot the suction rapidly draws the cups over the teats and the milk begins to flow into the milk pail, which is hung on the spout of the pump.

The teat cups are hollow and conical. Nearly an inch from the large end the cup is almost closed by a soft rubber diaphragm; this disk, being elastic, fits air-tight around the different-sized teats. The teats fill the conical cup except at the small end where suction is applied. The cup is made of three pieces of smooth hard rubber. To the end of the cup is attached a piece of glass tubing thru which the milk may be seen, and this is again connected with a small rubber tube. By means of a spigot in the tube the suction may be cut off when the teat is empty. The milk is conveyed from the spigot to the head where the milk from all four teats unites and passes into the large hose which carries it to the pail.

This machine has been in operation since 1892.

A POWER MILKER.

The accompanying illustration (pl. 2) shows a cow milker which has recently been put upon the market. It consists of an ordinary milk pail made of block tin and holding about 15 quarts. On top of this pail is a tight-fitting lid of aluminum. On this lid is mounted a pump or pulsator which works automatically and causes the intermittent action of the machine. Connections are made by means of rubber tubing to the exhaust and air-pressure pipes, which are laid thru the stable with convenient branches between the cows. Two rubber tubes, each about 3 feet long, are also connected with convenient nozzles on the lid, and on the other end of each are 4 cups which fit snugly over the cow's teats, 2 cows being milked into one pail. As the pulsator oscillates (at the rate of about 60 times a minute) the vacuum is alternately turned on and off, the teat cups causing suction and release at each alternate stroke.

The machinery for operating the pulsator consists of an exhaust pump and a compressor; the exhaust produces the suction and operates the pulsator in one direction, while the compressor operates the pulsator in the opposite direction.

A MILKER DESIGNED FOR EITHER HAND OR POWER.

The milking machine shown in Plate 3 consists of a simple air pump, composed of two cylinders, each of which is independent of the other in its action. One cylinder milks one cow, and one the other. The valve chambers, supported at the ends of the rods, are for the purpose of keeping the milk from running back into the pump, and also to give the pump sufficient and continued suction for the space of about ten to fifteen seconds. When the pressure is off of one of these valve chambers the milk flows from it of its own gravity into the pail. Each cow can be milked separately, or both can be milked into one pail, as desired. Cows can be milked into either open or closed pails. The machine is operated by either hand or power, the hand machine being convertible into a power machine by simply bolting an air device to it. In the operation of the power machine it is necessary to pipe the stables, a comprest air tank being required, which must be filled by some power running an air compressor. There are no pulsators or vacuum pumps in the construction of the machine. The teat cups are provided with a rubber sleeve.

THE MACHINE USED IN THE INVESTIGATION.

With this machine the milk is drawn by intermittent suction. The suction may be created by either a vacuum pump or a steam ejector. Connected with the vacuum pump is a vacuum reservoir and a pipe running the whole length of the cow stable, with a connection valve or vacuum cock between each pair of cows. A safety valve is connected to the reservoir to prevent the vacuum from running higher than is desired.

The machine itself (pl. 4, fig. 1) consists of a heavy tin pail, which is cone-shaped and holds about 55 pounds of milk. The cover of this pail is a disk, in which is a vacuum motor which produces the pulsations in drawing the milk from the teats. The cover fits the pail tightly and excludes all air.

To operate the machine it is placed between the pair of cows to be milked. A rubber tube connects the pail top or pulsator with the vacuum cock above the stanchions. On opening the cock the air is drawn from the pail and the motor immediately starts. The degree of pressure maintained is about one-half atmosphere, or 7½ pounds to the square inch. Leading from the pail cover or pulsator are two flexible tubes besides the one leading to the vacuum cock above the stanchions. At the end of each tube are 4 cups, which are fitted over the teats of the cow. The milk from the 2 cows is discharged into one pail (pl. 4, fig. 2). In operation the machine makes a low, clicking sound, which is caused by the motor. The vacuum pulsations run from 50 to 70 per minute and may be easily adjusted to the speed

Fig. 1.—A Foot-power Cow Milker with Attachments.

Fig. 2.—The Same Machine in Operation.

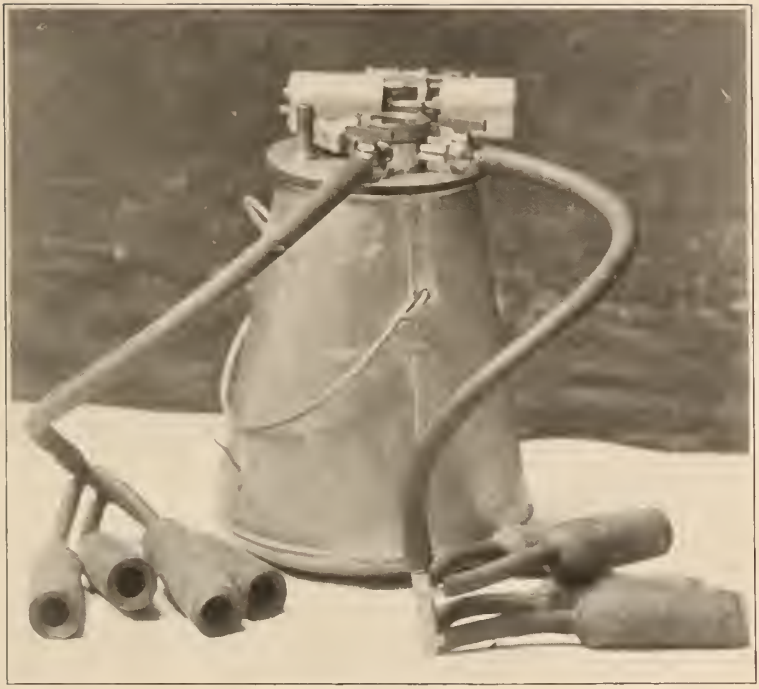

FIG. 1.—A POWER MILKER WITH ATTACHMENTS.

FIG. 2.—THE SAME MACHINE IN OPERATION.

FIG. 1.—MILKING MACHINE DESIGNED FOR USE WITH EITHER HAND OR POWER.

FIG. 2.—THE SAME MACHINE IN OPERATION.

FIG. 1.—MILKING MACHINE USED IN EXPERIMENTS.

FIG. 2.—THE SAME MACHINE IN OPERATION.

a decrease in yield, but the milk would be of poorer quality. A similar effect is produced in the case of machine milking. If the engine, or whatever power is employed to work the pumps, stops for any cause during the milking, a marked decrease in the yield of milk results.

Gasoline engines.—These are most commonly employed for power at the present time.

Electric motors.—Some farmers located near cities find electricity the most convenient power. This has worked successfully on two farms at least. In one case a trolley line passes near the barn and a wire is attached to the main trolley wire and connected with a 1-horsepower electric motor inside of the building. As electric roads are now being rapidly built thru country districts it is quite possible that this may prove a popular method of securing power to operate cow milkers.

Steam power.—Steam engines are employed on some farms, and they will be found to work satisfactorily in supplying power to operate the milking machines. Where steam is used on farms for other purposes it can be made to run the milkers with but little extra expense.

EXPERIMENTS IN WHICH HAND AND MACHINE MILKING WERE COMPARED.

Two experiments were conducted by the Dairy Division in which tests were made to determine the time required to milk by hand and by machine. The yield of milk, its chemical composition, and other points that were considered of interest to dairymen, were also studied.

EXPERIMENT NO. 1.

From a herd of 13 cows, 8 were selected for this test, the others being nearly dry. The animals were Jerseys and Holsteins, all 5 years old or over. This herd had been milked with the machines for over three years.

The cows were divided into two lots of 4 each in such a way that each lot gave practically the same amount of milk. The test continued for thirty days and was divided into three periods of ten days each. At the beginning of the first period, Lot I was milked by hand and Lot II by machine. At the end of each period of ten days the methods of milking the two lots of cows were reversed so that the results from milking by the two methods could be compared. The milking was all performed by one man.

TABLE 1.—*Machine milking: Time required to milk, and yield of milk and strippings.*

The cows and date.	Morning.				Evening.				Total for day.			
	Time required.	Yield of milk.			Time required.	Yield of milk.			Time required.	Yield of milk.		
		Machine milk.	Strippings.	Total.		Machine milk.	Strippings.	Total.		Machine milk.	Strippings.	Total yield.
LOT II, 4 COWS.	*Min.*	*Lbs.*	*Lbs.*	*Lbs.*	*Min.*	*Lbs.*	*Lbs.*	*Lbs.*	*Min.*	*Lbs.*	*Lbs.*	*Lbs.*
July 21	14.00	30.50	1.25	31.75	13.00	25.00	1.50	26.50	27.00	55.50	2.75	58.25
July 22	14.00	36.50	.75	37.25	12.00	34.75	.80	35.55	26.00	71.25	1.55	72.80
July 23	14.00	31.50	.50	32.00	13.00	28.00	[a] 8.10	36.10	27.00	59.50	8.60	68.10
July 24	13.50	36.50	.75	37.25	15.00	36.50	.50	37.00	28.50	73.00	1.25	74.25
July 25	14.50	35.00	.50	35.50	11.50	35.00	.50	35.50	26.00	70.00	1.00	71.00
July 26	13.00	36.50	.50	37.00	12.50	34.50	.50	35.00	25.50	71.00	1.00	72.00
July 27	12.50	34.00	.25	34.25	12.00	32.00	.60	32.60	24.50	66.00	.85	66.85
July 28	13.00	30.50	[b] 5.25	35.75	14.00	34.80	.40	35.20	27.00	65.30	5.65	70.95
July 29	13.00	38.00	.75	38.75	13.50	32.00	.40	32.40	26.50	70.00	1.15	71.15
July 30	12.00	37.50	.50	38.00	12.00	29.25	.90	30.15	24.00	66.75	1.40	68.15
Total	133.50	346.50	11.00	357.50	128.50	321.80	14.20	336.00	262.00	668.30	25.20	693.50
Daily average	13.35	34.65	1.10	35.75	12.85	32.18	1.42	33.60	26.20	66.83	2.52	69.35
LOT I, 4 COWS.												
July 31	13.00	30.00	.75	30.75	12.50	27.30	1.80	29.10	25.50	57.30	2.55	59.85
August 1	13.50	34.50	.75	35.25	14.00	27.30	.50	27.80	27.50	61.80	1.25	63.05
August 2	13.00	34.00	.50	34.50	13.00	27.00	.50	27.50	26.00	61.00	1.00	62.00
August 3	12.50	36.00	.50	36.50	13.00	24.00	1.00	25.00	25.50	60.00	1.50	61.50
August 4	12.00	32.00	.75	32.75	13.00	24.50	.75	25.25	25.00	56.50	1.50	58.00
August 5	13.00	34.50	.75	35.25	15.00	26.25	1.00	27.25	28.00	60.75	1.75	62.50
August 6	12.50	32.50	.75	33.25	14.00	25.50	.30	25.80	26.50	58.00	1.05	59.05
August 7	13.00	33.00	.50	33.50	14.00	27.25	.75	28.00	27.00	60.25	1.25	61.50
August 8	12.50	33.50	.50	34.00	15.50	27.75	.75	28.50	28.00	61.25	1.25	62.50
August 9	13.00	34.25	.50	34.75	13.00	34.00	.40	34.40	26.00	68.25	.90	69.15
Total	128.00	334.25	6.25	340.50	137.00	270.85	7.75	278.60	265.00	605.10	14.00	619.10
Daily average	12.80	33.42	.62	34.05	13.70	27.08	.77	27.86	26.50	60.51	1.40	61.91
LOT II, 4 COWS.												
August 10	11.00	36.00	.50	36.50	11.25	30.10	1.00	31.10	22.25	66.10	1.50	67.60
August 11	12.00	36.00	.25	36.25	12.00	32.00	.25	32.25	24.00	68.00	.50	68 50
August 12	13.50	33.00	.50	33.50	15.00	[c] 27.75	5.25	33.00	28.50	60.75	5.75	66 50
August 13	12.50	34.00	.25	34.25	13.00	[d] 31.00	3.75	34.75	25.50	65.00	4.00	69 00
August 14	13.00	40.00	.25	40.25	16.00	26.00	1.50	27.50	29.00	66.00	1.75	67.75
August 15	14.00	39.50	.25	39.75	16.50	33.50	.25	33.75	30.50	73.00	.50	73.50
August 16	13.00	35.50	.50	36.00	13.50	31.00	.70	31.70	26.50	66.50	1.20	67.70
August 17	12.50	34.50	.25	34.75	14.00	36.50	.25	36.75	26.50	71.00	.50	71.50
August 18	13.50	33.00	.25	33.25	14.50	40.00	.50	40.50	28.00	73.00	.75	73.75
August 19	14.00	40.00	.50	40.50	16.00	[e] 37.50	5.75	43.25	30.00	77.50	6.25	83.75
Total	129.00	361.50	3.50	365.00	141.75	325.35	19.20	344.55	270.75	686.85	22.70	709.50
Daily average	12.90	36.15	.35	36.50	14.17	32.53	1.92	34.45	27.07	68.68	2.27	70.95
Grand total	390.50	1,042.25	20.75	1,063.00	407.25	918.00	41.15	959.15	797.75	1,960.25	61.90	2,022.10
General average	13.02	34.74	.69	35.43	13.57	30.60	1.37	31.97	26.59	65.34	2.06	67.40

[a] One cow held up milk (7.5 pounds) on account of stranger being in barn.
[b] One cow held up milk (5 pounds) on account of stranger being in barn.
[c] Black cow held up milk and gave 4.75 pounds by hand.
[d] Black cow held up milk and gave 3 pounds by hand (stranger in barn).
[e] Black cow held up milk and gave 5 pounds by hand.

TABLE 2.—*Hand milking: Time required to milk, and yield of milk and strippings.*

The cows and date.	Morning.				Evening.				Total for day.			
	Time required.	Yield of milk.			Time required.	Yield of milk.			Time required.	Yield of milk.		
		First yield.	Strippings.	Total.		First yield.	Strippings.	Total.		First yield.	Strippings.	Total.
LOT I, 4 COWS.	*Min.*	*Lbs.*	*Lbs.*	*Lbs.*	*Min.*	*Lbs.*	*Lbs.*	*Lbs.*	*Min.*	*Lbs.*	*Lbs.*	*Lbs.*
July 21	21.00	31.00	1.50	32.50	20.00	32.20	1.80	34.00	41.000	63.20	3.300	66.500
July 22	22.00	36.00	1.50	37.50	16.00	29.20	1.00	30.20	38.000	65.20	2.500	67.700
July 23	21.50	34.00	1.00	35.00	17.00	28.20	1.70	29.90	38.500	62.20	2.700	64.900
July 24	21.00	32.00	1.25	33.25	16.00	33.00	1.25	34.25	37.000	65.00	2.500	67.500
July 25	24.50	35.00	1.25	36.25	20.50	29.75	1.25	31.00	45.000	64.75	2.500	67.250
July 26	19.50	35.50	1.00	36.50	17.00	31.50	1.50	36.00	36.500	70.00	2.500	72.500
July 27	18.50	32.00	1.25	33.25	19.00	32.00	1.00	33.00	37.500	64.00	2.250	66.250
July 28	24.00	35.00	1.00	36.00	17.25	33.00	1.00	34.00	41.250	68.00	2.000	70.000
July 29	20.00	35.00	1.50	36.50	18.50	33.80	1.10	34.90	38.500	68.80	2.600	71.400
July 30	21.00	32.50	1.75	34.25	16.00	30.00	1.90	31.90	37.000	62.50	3.650	66.150
Total	213.00	338.00	13.00	351.00	177.25	315.65	13.50	329.15	390.250	653.65	26.500	680.150
Daily average	21.30	33.80	1.30	35.10	17.72	31.56	1.35	32.91	39.025	65.36	2.650	68.015
LOT II, 4 COWS.												
July 31	26.00	37.00	.75	37.75	21.00	33.50	1.00	34.50	47.000	70.50	1.750	72.250
August 1	25.50	31.00	.75	31.75	20.00	31.60	.50	32.10	45.500	62.60	1.250	63.850
August 2	21.50	34.00	.75	34.75	19.00	33.00	.75	33.75	40.500	67.00	1.500	68.500
August 3	23.00	26.00	[a] 7.50	33.50	21.00	31.50	.90	32.40	44.000	57.50	[a] 8.400	65.900
August 4	23.50	31.00	.75	31.75	20.00	33.75	1.30	35.05	43.500	64.75	2.050	66.800
August 5	21.00	36.00	.75	36.75	22.50	32.00	1.25	33.25	43.500	68.00	2.000	70.000
August 6	24.00	31.50	.50	32.00	19.00	31.00	.50	31.50	43.000	62.50	1.000	63.500
August 7	22.00	35.00	.50	35.50	23.00	30.70	1.00	31.70	45.000	65.70	1.500	67.200
August 8	23.00	36.50	.50	37.00	21.50	34.20	.75	34.95	44.500	70.70	1.250	71.950
August 9	24.00	36.00	.50	36.50	19.00	33.40	.50	33.90	43.000	69.40	1.000	70.400
Total	233.50	334.00	13.25	347.25	206.00	324.65	8.45	333.10	439.500	658.65	21.700	680.350
Daily average	23.35	33.40	1.32	34.72	20.60	32.46	.84	33.31	43.950	65.86	2.170	68.035
LOT I, 4 COWS.												
August 10	21.00	28.00	1.00	29.00	16.00	25.75	2.00	27.75	37.000	53.75	3.000	56.750
August 11	24.00	31.00	.75	31.75	19.00	24.00	.80	24.80	43.000	55.00	1.550	56.550
August 12	21.00	28.50	.50	29.00	20.00	25.25	1.10	26.35	41.000	53.75	1.600	55.350
August 13	21.00	30.00	1.25	31.25	16.00	28.50	1.25	29.75	37.000	58.50	2.500	61.000
August 14	21.00	33.00	.25	33.25	19.00	26.25	1.00	27.25	40.000	59.25	1.250	60.500
August 15	20.00	32.00	.50	32.50	19.00	29.00	1.25	30.25	39.000	61.00	1.750	62.750
August 16	21.00	30.00	1.00	31.00	16.00	28.20	1.50	29.70	37.000	58.20	2.500	60.700
August 17	21.00	31.00	.75	31.75	18.00	29.00	1.25	30.25	39.000	60.00	2.000	62.000
August 18	20.00	31.00	.75	31.75	17.00	32.00	1.25	33.25	37.000	63.00	2.000	65.000
August 19	20.00	32.50	.75	33.25	18.00	31.50	1.25	32.75	38.000	64.00	2.000	66.000
Total	210.00	307.00	7.50	314.50	178.00	279.45	12.65	292.10	388.000	586.45	20.150	606.600
Daily average	21.00	30.70	.75	31.45	17.80	27.94	1.26	29.21	38.800	58.64	2.015	60.660
Grand total	656.50	979.00	33.75	1,012.75	561.25	919.75	34.60	954.35	1,217.750	1,898.75	68.350	1,967.100
General average	21.88	32.63	1.12	33.76	18.71	30.66	1.15	31.81	40.592	63.29	2.285	65.570

[a] One cow held up milk (7 pounds).

TIME REQUIRED FOR HAND AND MACHINE MILKING COMPARED.

Naturally one of the first questions asked when a dairyman is considering the installation of milking machines is: How much time will be saved by their use? In the experiment outlined above one man performed the milking, 1 cow milker being used in case of the lots milked by machinery. The machine was operated by a 1-horsepower electric motor. By referring to Tables 1 and 2 the reader can readily compare from day to day the time required to milk by the two methods. A glance at the general averages for thirty days shows that the average time required for one man to milk 4 cows with the machine was 13.02 minutes in the morning and 13.57 minutes in the evening, or a total of 26.59 minutes for the day. These figures include the time used in putting the machine in place and adjusting the teat cups, about one-fourth minute per cow being required to adjust them properly.

In considering the time, the amount of milk secured should also be considered. Other things being equal, cows producing a large amount of milk require the most time to perform the milking. In case of the 4 cows milked by hand it will be noted that it took an average of 21.88 minutes to milk them in the morning and 18.71 minutes in the evening, or a total of 40.59 minutes for the day. There was therefore a daily saving of 3.5 minutes per cow, or 14 minutes on 4 cows, thru the use of the machines.

It should be noted, however, that the time saved by the employment of machines was not the result of greater speed in milking, but in the operator's ability to milk 2 cows at once. Indeed, one man can look after 5 machines milking 10 cows at once, thus greatly increasing this saving of time. (See experiment No. 2.)

Speed of the machine.—As stated in the description, the pulsator can be adjusted so that the action will be fast or slow; 50 to 60 pulsations per minute is the rate usually recommended. The more rapid the pulsations the faster the machine will milk, up to a certain limit. The writer saw one cow, giving a good flow, milked absolutely clean with a machine in 2¼ minutes, the number of pulsations being 150 per minute. It is believed, however, that such rapid milking for any length of time has a bad influence upon the cow and after a time she might object to the machine and refuse to give down her milk.

Cows vary greatly individually, and it is the best plan to adjust the speed of the machine as closely as possible to the requirements of each cow. Cows with short teats can be milked with the machine set at greater speed than cows with large, long teats. The ordinary type of

Ayrshire cow, for example, can probably be milked by more rapid pulsations than the Holstein. Those acquainted with milking these two types of cows by hand know this to be true, and that in milking some cows the milk is ready to be drawn as fast as the milker can manipulate the teats.

While the machines were in operation the attendants massaged the udders of the cows and watched to see that they were milking freely. Care was taken to treat the animals as nearly as possible the same at each milking, so they would become accustomed to the machines.

YIELD OF MILK FROM HAND AND MACHINE MILKING COMPARED.

The yield of milk is perhaps the most important matter to the dairyman. Any method of milking that has a tendency to decrease the flow to any appreciable extent can hardly be considered practicable. This point was studied for a period of thirty days in this experiment with the milking machine. While a much longer period is necessary to settle this question, the results secured indicate at least what may be expected when the machines are properly handled. In this test the cows were carefully handled, care being taken to adjust the teat cups to suit the individuality of each cow, also to use cups of the same size on each cow every time.

As already stated, two lots of cows were selected that yielded practically the same amount of milk. Referring to Tables 1 and 2 it will be noted that the total yield of milk for 4 cows during thirty days was 1,898.75 pounds from hand milking[a] and 1,960.25 pounds from machine milking,[b] not including strippings—a difference of 61.5 pounds, or 3.24 per cent, in favor of the machine. A study of the yields of the different lots of cows for the different periods shows that Lot I, which started with hand milking, gradually decreased in milk flow when changed to the machines and also continued to decrease when changed again to hand milking. The yields of Lot II, which began with machine milking, show that these cows decreased when changed to hand milking and materially increased in yield when changed back again to machine milking.

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[a] One cow held up part of her milk one day (see Table 2).

[b] One cow held up a small quantity of milk a few times and was finished by hand (see Table 1).

The yields of Lots I and II for the three 10-day periods were as follows:

Yields from machine milking and hand milking compared.

	Pounds.
Lot I, 4 cows:	
First 10-day period, cows milked by hand	653.65
Second 10-day period, cows milked by machine	605.10
Third 10-day period, cows milked by hand	586.45
Lot II, 4 cows:	
First 10-day period, cows milked by machine	668.30
Second 10-day period, cows milked by hand	658.65
Third 10-day period, cows milked by machine	686.85

As the cows of Lot II increased in yield when changed back again to machine milking in the third period, when the natural tendency was to decrease owing to advance in lactation, it appears that the machine had a favorable influence upon the production of this lot of cows.

As Lot I was used during two periods of the hand-milking test and in only one period with the machine test, and Lot II the reverse, a fairer comparison may be drawn by averaging the yields where the same lot of cows was used twice in either test. The result of this method of comparison is shown in the tabulation which follows:

Comparison of the milk yield of the two lots of cows (not including strippings).

	Pounds.
Hand milking:	
Lot I, average of first and third periods	620.05
Lot II, second period	658.65
Total	1,278.70
Machine milking:	
Lot II, average of first and third periods	677.50
Lot I, second period	605.10
Total	1,282.60

It appears that the yield of milk, not including strippings, amounted to 1,278.7 pounds from hand milking and 1,282.6 from machine milking, a difference of 3.9 pounds also in favor of the machine. This further comparison will serve to strengthen the conclusion already given that when the machines are properly handled and carefully adjusted to suit the needs of individual cows the yield of milk compares favorably with that of hand milking.

THORONESS OF HAND AND MACHINE MILKING COMPARED.

A machine that does not milk cows clean, or at least as clean as the average farm hand does, is of but little service to dairymen. This point was tested as thoroly as possible in the experiment just described. The man who milked the cows by hand in this experiment was instructed to milk the cows as normally as possible and not to go to extremes in either direction. It is believed that a fair trial was made in this respect.

Referring to Table 1 it will be observed that the amount of strippings was fairly uniform from day to day in case of both hand and machine milking. A comparison of the amount of strippings from each lot of cows for the three 10-day periods is shown in the following tabulation:

Comparison of amount of strippings in hand and machine milking.

	Pounds.
Hand milking:	
Lot I, first period	26.50
Lot II, second period	21.70
Lot I, third period	20.15
Total	68.35
Machine milking:	
Lot II, first period	25.20
Lot I, second period	14.00
Lot II, third period	22.70
Total	61.90

The total strippings from hand milking for the 4 cows for thirty days is shown to be 68.35 pounds, and from machine milking 61.90 pounds, or 6.45 pounds less for the machine. The average strippings per cow for each milking was 4.55 ounces by hand and 4.12 ounces by machine.

The composition of the milk was not determined in this experiment.

EXPERIMENT NO. 2.

This experiment was conducted with 20 cows selected from a herd of 65. All kinds of cows were selected for the test, including hard and easy milkers, heifers, and mature animals, and fresh cows as well as those advanced in lactation; also including cows of nervous temperament which it was known did not take kindly to the machine. This was done in order that a thoro study might be made. The 20 cows were divided into two lots of 10 each, which we will designate as Lots I and II.

Lot I was milked by hand and Lot II by machine for a period of 10 days; the methods of milking were then reversed and Lot I was milked by machine and Lot II by hand, 2 days being allowed between the periods to make the change. Five machines were used to milk the 10 cows. These were handled by one man. One man also milked the 10 cows by hand the greater part of the time. Whenever more than one man was employed the results were put on the basis of one man; that is, if two men milked the 10 cows in 40 minutes this was considered equivalent to one man milking 80 minutes. This experiment differed from the one previously described in that more cows were included and less attempt was made to adjust the teat cups to the different cows or to use the same machine on the same pair of cows every time, this matter being left largely to the dairyman in charge. These points will be considered in studying the results.

TABLE 3.—*A comparison of the yield and composition of milk from hand and machine milking.*

HAND MILKING.

The cows and date.	Morning.						Evening.						For the day.					
		Yield.			Composition.			Yield.			Composition.			Yield.			Composition.	
	Time required.	First milk.	Strippings.	Total.	Fat.[a]	Solids not fat.[a]	Time required.	First milk.	Strippings.	Total.	Fat.[a]	Solids not fat.[a]	Time required.	First milk.	Strippings.	Total.	Fat.[a]	Solids not fat.[a]
LOT I, 10 COWS.	*Min.*	*Pounds.*	*Lbs.*	*Pounds.*	*Per ct.*	*Per ct.*	*Min.*	*Pounds.*	*Lbs.*	*Pounds.*	*Per ct.*	*Per ct.*	*Min.*	*Pounds.*	*Lbs.*	*Pounds.*	*Per ct.*	*Per ct.*
July 26	82.0	121.0	1.00	122.00	3.70	8.41	72.00	117.50	1.00	118.50	4.60	8.38	154.00	238.50	2.00	240.50	4.15	8.40
July 27	80.0	101.0	1.00	102.00	4.20	8.38	54.00	95.00	2.00	97.00	3.80	8.75	134.00	196.00	3.00	199.00	4.00	8.57
July 28	75.0	123.0	2.00	125.00	3.70	8.65	80.00	106.00	2.50	108.50	3.70	8.65	155.00	229.00	4.50	233.50	3.70	8.65
July 29	70.0	119.0	1.50	120.50	3.60	8.53	75.00	101.50	1.50	103.00	4.00	8.69	145.00	221.50	3.00	223.50	3.80	8.61
July 30	80.0	118.0	1.00	119.00	3.50	8.59	70.00	103.50	1.50	105.00	4.00	8.56	150.00	221.50	2.50	224.00	3.75	8.58
July 31	80.0	121.0	1.50	122.50	3.40	8.44	74.00	97.00	2.00	99.00	3.90	8.54	154.00	218.00	3.50	221.50	3.65	8.49
August 1	80.0	121.5	3.00	124.50	3.60	8.48	70.00	96.00	1.50	97.50	3.90	8.67	150.00	217.50	4.50	222.00	3.75	8.58
August 2	75.0	110.0	1.00	111.00	3.70	8.70	65.00	110.00	1.50	111.50	3.80	8.62	140.00	220.00	2.50	222.50	3.75	8.66
August 3	80.0	120.5	1.00	121.50	3.60	8.61	80.00	91.00	1.00	92.00	3.90	8.79	160.00	211.50	2.00	213.50	3.75	8.70
August 4	85.0	117.0	1.50	118.50	3.90	8.61	70.00	101.00	1.50	102.50	3.90	8.61	155.00	218.00	3.00	221.00	3.90	8.61
Total	787.0	1,172.0	14.50	1,186.50	.....	.....	710.00	1,018.50	16.00	1,034.50	.....	.....	1,497.00	2,190.50	30.50	2,221.00	.....	.....
Average	78.7	117.2	1.45	118.65	3.70	8.54	71.00	101.85	1.60	103.45	3.95	8.62	149.70	219.05	3.05	222.10	3.82	8.58
LOT II, 10 COWS.																		
August 7	85.0	116.0	1.00	117.00	3.40	8.37	80.00	112.00	1.50	113.50	3.80	8.37	165.00	228.00	2.50	230.50	3.60	8.37
August 8	80.0	123.0	1.50	124.50	3.40	8.16	80.00	101.00	2.00	103.00	3.60	8.48	160.00	224.00	3.50	227.50	3.50	8.47
August 9	90.0	125.0	4.00	129.00	3.50	8.41	80.00	106.50	1.50	108.00	3.40	8.34	170.00	231.50	5.50	237.00	3.45	8.38
August 10	90.0	116.0	1.00	117.00	3.70	8.55	80.00	107.00	4.50	111.50	3.80	8.32	170.00	223.00	5.50	228.50	3.75	8.44
August 11	80.0	107.0	2.00	109.00	3.70	8.57	75.00	107.00	2.00	109.00	4.40	8.49	155.00	214.00	4.00	218.00	4.05	8.53
August 12	90.0	121.0	1.00	122.00	3.70	8.47	75.00	99.00	1.50	100.50	3.60	8.48	165.00	220.00	2.50	222.50	3.65	8.48
August 13	80.0	111.0	1.50	112.50	3.80	8.47	85.00	91.00	1.00	92.00	3.90	8.42	165.00	202.00	2.50	204.50	3.85	8.45
August 14	88.0	111.0	2.00	113.00	3.90	8.51	70.00	100.00	1.50	101.50	3.80	8.57	158.00	211.00	3.50	214.50	3.85	8.54
August 15	75.0	107.0	1.00	108.00	3.40	8.54	73.00	97.00	3.50	100.50	3.20	8.43	148.00	204.00	4.50	208.50	3.45	8.49
August 16	76.0	119.0	2.00	121.00	4.00	8.41	70.00	101.00	1.50	105.50	4.00	8.46	146.00	223.00	3.50	226.50	4.00	8.44
Total	834.0	1,156.0	17.00	1,173.00	.....	.....	768.00	1,024.50	20.50	1,045.00	.....	.....	1,602.00	2,180.50	37.50	2,218.00	.....	.....
Average	83.4	115.6	1.70	117.30	3.65	8.48	76.80	102.45	2.05	104.50	3.75	8.44	160.20	218.05	3.75	221.80	3.72	8.46
Grand total	1,621.0	232.8	31.50	1,359.50	.....	.....	1,478.00	2,043.00	36.50	2,079.50	.....	.....	3,099.00	4,371.00	.....	4,439.00	.....	.....
General average.	81.0	116.4	1.57	117.97	3.67	8.51	73.90	102.15	1.82	103.97	3.85	8.53	154.90	218.55	3.40	221.95	3.77	8.52

LOT II, 10 COWS.																		
July 26	23.0	97.0	1.50	98.50	3.30	8.45	20.00	101.50	1.50	103.00	3.50	8.46	43.00	198.50	3.00	201.50	3.40	8.46
July 27	12.0	93.0	3.50	96.50	3.00	8.49	[b]27.00	94.00	2.00	96.00	4.00	8.53	39.00	187.00	5.50	192.50	3.50	8.51
July 28	22.0	110.0	2.50	112.50	3.40	8.82	17.00	106.00	2.50	108.50	3.90	8.29	39.00	216.00	5.00	221.00	3.65	8.56
July 29	20.0	116.0	2.50	118.50	3.10	8.43	20.00	90.00	1.50	91.50	3.40	8.57	40.00	206.00	4.00	210.00	3.25	8.50
July 30	20.0	100.0	6.00	106.00	3.60	8.88	15.00	[c]101.00	1.50	102.50	3.50	8.59	35.00	201.00	7.50	208.50	3.55	8.74
July 31	15.0	119.5	1.50	121.00	3.10	8.51	[d]13.00	87.00	3.50	90.50	2.70	8.54	28.00	206.50	5.00	211.50	2.90	8.53
August 1	17.0	115.0	2.00	117.00	2.70	8.39	17.00	90.00	2.50	92.50	3.40	8.59	34.00	205.00	4.50	209.50	3.05	8.49
August 2	15.0	[e]130.0	2.00	132.00	3.20	8.73	13.50	[c]106.00	3.50	109.50	3.50	8.53	28.50	236.00	5.50	241.50	3.35	8.63
August 3	22.0	[e]110.5	1.50	112.00	3.20	8.50	17.00	[c]87.00	1.50	88.50	4.00	8.71	39.00	197.50	3.00	200.50	3.60	8.61
August 4	20.0	[e]130.0	2.00	132.00	3.20	8.50	20.00	108.00	2.00	110.00	3.80	8.57	40.00	238.00	4.00	242.00	3.50	8.54
Total	186.0	1,121.0	25.00	1,146.00	.....	.....	179.50	970.50	22.00	992.50	.....	.....	365.50	2,091.50	47.00	2,138.50	.....	.....
Average	18.6	112.1	2.50	114.60	3.20	8.57	17.95	97.05	2.20	99.25	3.60	8.54	36.55	209.15	4.70	213.85	3.37	8.55
LOT I, 10 COWS.																		
August 7	17.0	112.0	2.00	114.00	3.70	8.43	15.00	94.00	1.50	95.50	4.20	8.68	32.00	206.00	3.50	209.50	3.95	8.56
August 8	20.0	123.0	1.00	124.00	3.20	9.17	17.00	102.00	2.00	104.00	3.80	8.37	37.00	225.00	3.00	228.00	3.50	8.77
August 9	23.0	[e]112.0	2.00	114.00	3.10	8.45	21.00	100.00	1.00	101.00	4.10	8.33	44.00	212.00	3.00	215.00	3.60	8.39
August 10	20.0	98.0	2.50	100.50	3.40	8.64	21.00	101.00	1.50	102.50	3.80	8.42	41.00	199.00	4.00	203.00	3.60	8.53
August 11	18.0	101.0	.50	101.50	3.70	8.70	14.00	102.00	2.50	104.50	3.80	8.67	32.00	203.00	3.00	206.00	3.75	8.69
August 12	16.0	85.0	1.50	86.50	3.70	8.45	17.00	87.50	1.50	89.00	3.50	8.81	33.00	172.50	3.00	175.50	3.60	8.63
August 13	22.0	[e]98.0	1.50	99.50	3.50	8.83	12.00	81.00	1.00	82.00	4.00	8.43	34.00	179.00	2.50	181.50	3.75	8.63
August 14	25.0	100.0	6.00	106.00	3.50	8.63	22.00	84.50	2.00	86.50	3.20	8.83	47.00	184.50	8.00	192.50	3.35	8.73
August 15	20.0	102.0	1.50	103.50	3.30	8.64	17.00	92.00	1.00	93.00	3.80	8.42	37.00	194.00	2.50	196.50	3.55	8.53
August 16	21.0	103.0	1.20	104.20	3.20	8.70	18.00	93.00	4.50	97.50	3.50	8.21	39.00	196.00	5.70	201.70	3.35	8.46
Total	202.0	1,034.0	19.70	1,064.50	.....	.....	174.00	937.00	18.50	955.50	.....	.....	376.00	1,971.00	38.20	2,009.20	.....	.....
Average	20.2	103.4	1.97	106.45	3.50	8.66	17.40	93.70	1.85	95.55	3.90	8.52	37.60	197.10	3.82	200.92	3.60	8.59
Grand total	388.0	2,155.0	44.70	2,210.50	.....	.....	353.50	1,907.50	40.50	1,948.00	.....	.....	741.50	4,062.50	85.20	4,147.70	.....	.....
General average.	19.4	107.7	2.23	110.52	3.30	8.61	17.67	95.37	2.02	97.40	3.75	8.53	37.07	203.12	4.26	207.39	3.49	8.57

[a] Average of percentages only.
[b] Cow had inflamed udder, requiring longer time to milk.
[c] Too small teat cups used on cow, causing her to hold up milk.
[d] One hundred and ten pulsations.
[e] One to 3 cows held up some of their milk and were finished by hand.

TIME REQUIRED FOR HAND AND MACHINE MILKING COMPARED.

The accompanying table shows the time required to milk the cows by the two methods during the different periods. In this experiment one man handled 5 machines with little difficulty. The man who milked the cows by hand was unusually thoro and took somewhat more time to do the work than the average milker.

It will be noted that the average time required for one man to milk the 10 cows with the machines for 20 days was 19.4 minutes in the morning and 17.67 minutes in the evening, or a total of 37.07 minutes for the day. The time stated includes the time required for putting the machines in place, adjusting the teat cups, and milking; the average time per cow being 1.94 minutes in the morning and 1.76 minutes in the evening, or a total of 3.7 minutes for the day.

In the case of the 10 cows milked by hand it will be noted that it required for the 20 days an average of 81 minutes in the morning and 73.9 minutes in the evening, or a total for the day of 154.9. The average time required per cow was therefore 8.1 minutes in the morning and 7.39 minutes in the evening, or a total of 15.49 minutes for the day. On the basis of these results the daily saving per cow thru the use of the machines amounted to 11.79 minutes, or 117.9 minutes for the 10 cows. Carrying the comparison still further, the saving for 60 cows (the number in this herd) would amount to 11.7 hours per day if one man performed all of the work, which of course would not be possible for a herd of this size, altho the writer has known one man to milk 60 cows with 6 machines on more than one occasion, the time required being about 2 hours. If, however, we include the time of the man who removed the milk and assisted in manipulating the cow's udders the saving of time is reduced to one-half, or 58.45 minutes per day for the 10 cows. These figures furnish sufficient proof for the statement that the machines are "time savers."

YIELD OF MILK FROM HAND AND MACHINE MILKING COMPARED.

As previously stated, but little attention was given to properly adjusting the machines by the attendants in this herd. Further than this, it was known that 1 or 2 of the cows selected did not take kindly to the machine, but it was desired to have the cows in the test represent the average of the herd. While a longer period than 20 days would have been desirable, the results indicate, at least, what may be expected under the conditions which prevailed during this test.

Referring to Table 3, it will be observed that the total yield of milk for 10 cows during the 20 days was 4,371 pounds from hand milking and 4,062.5 pounds from machine milking, not including strippings—a difference of 308.5 pounds, or 7.59 per cent, in favor of hand milking.

This result is not surprising when we consider the careless manner in which the machines were adjusted to the animals, and that this frequently resulted in the animals holding up their milk. Further, the fact should be noted that the hand milker in this instance was unusually careful, taking an average of 7.75 minutes to milk a cow at each milking.

The results tend to show that where milking machines are used carelessly they are a disadvantage to the dairyman from the standpoint of yield. The same holds true of other machinery on the farm; the more complex it is the more care and skill is required to secure the best results; but with skill and care the more machinery the better, up to a certain limit. This is brought out in experiment No. 1, where the milking machine held its own or showed an advantage at every point.

THOROUGHNESS OF HAND AND MACHINE MILKING COMPARED.

As previously stated, the man who did the milking in this experiment was an unusually thoro milker and consequently took more time for milking than the average milker. While possibly it would have been better to have employed an average milker in this experiment in order to make a fair comparison, the question as to whether the milking was thoro by both methods can be made clear. In a few instances 1 or 2 cows refused to give down part of their milk (probably owing to the teat cups not being of the proper size). This of course increased the amount classed as strippings. A comparison of the amount of strippings (including the amount held up by the machine-milked cows, as explained above) from each lot of cows for the 10-day periods is as follows:

Comparison of amount of strippings in experiment No. 2.

	Pounds.
Hand milking:	
Lot I, first period	30.50
Lot II, second period	37.50
Total	68.00
Machine milking:	
Lot II, first period	47.00
Lot I, second period	38.20
Total	85.20

The total strippings from the hand and machine milking for the 10 cows during 20 days is thus shown to be 68 pounds and 85.2 pounds, respectively. On this basis the average strippings per cow at each milking amounted to 2.7 ounces by hand and 3.4 ounces by machine. In either case the results show unusually clean milking.

QUALITY OF THE MILK.

Percentage of butter fat in milk.—A sample of the mixt milk was taken at every milking in experiment No. 2 and tested for percentage of fat by the Babcock method. The results of the daily tests are shown in Table 3 and the average for the different periods has been brought together for ready comparison in the following tabulation:

Percentage of butter fat in milk drawn by hand and by machine.

	Per cent.
Hand milking:	
Lot I, first period (10 days)	3.82
Lot II, second period (10 days)	3.72
Average	3.77
Machine milking:	
Lot II, first period (10 days)	3.37
Lot I, second period (10 days)	3.60
Average	3.49

It will be noted that the average percentage of fat in the milk drawn by hand for the twenty days was 3.77 and in the milk drawn by machine 3.49, a considerable difference in favor of the hand milking.

A calculation of the yield of butter from the 4,439 pounds of milk resulting from the hand milking (Table 3), with an average of 3.77 per cent of butter fat, gives about 195.25 pounds of butter. The same amount of milk with an average of 3.49 per cent of butter fat would yield about 180.75 pounds of butter, or 14.50 pounds less owing to the lower percentage of butter fat presumably resulting from the use of the machines. If the yield of butter be calculated from the 4,147.7 pounds of milk resulting from machine milking, with an average of 3.49 per cent of fat, it will be found to be about 169 pounds. Thus, if we allow for both the lower yield and the lower percentage of fat in the milk in this experiment, the balance against the machine with 10 cows for twenty days would be about 26 pounds of butter, or about 13 per cent. This appears to be quite an unfavorable showing for the machine, but further experiments are necessary to determine the effect of machine milking on the composition of milk, as it is always unsafe to base general conclusions on the results of a single experiment.

Percentage of solids not fat.[a]—The percentage of solids not fat was determined by means of the lactometer. Tests were made from samples taken both morning and evening. The detailed results are given in Table 3, but in order to make a more ready comparison only the averages are presented here.

[a] These tests were made by Prof. W. A. Stocking.

Percentage of solids not fat in milk drawn by hand and by machine.

	Per cent.
Hand milking:	
Lot I, first period (10 days)	8.58
Lot II, second period (10 days)	8.46
Average	8.52
Machine milking:	
Lot II, first period (10 days)	8.55
Lot I, second period (10 days)	8.59
Average	8.57

The final averages shown above for the solids not fat are very close, being 8.52 and 8.57, respectively, for the hand and machine milk. While further study should be made on this point, the figures secured indicate that there is practically no difference in the amount of solids not fat between machine and hand drawn milk.

GENERAL CONSIDERATIONS.

EFFECTS OF MILKING MACHINES UPON THE COWS.

First time machine is used.—It is of interest to note how the milking machine affects a herd of cows the first time it is used. The writer was present in a barn of about 40 cows on one occasion the first time the machines were put in operation. Some of the animals were a little restless at first, owing to the sight of the machines and the clicking of the pulsators, but soon they became quiet and reconciled to their action. One feature which is perhaps a little surprising is that heifers took to the machines as readily as the older cows. Only one cow in the herd in question made any disturbance at all while the machines were being attached, and this was due principally to attaching the machine on the opposite side from that on which the cow had been accustomed to be milked by hand. This cow, however, soon became quiet. The majority of the cows appeared to like the machines, and stood quietly chewing their cuds without manifesting any discomfort. A careful examination was made of the cows' teats and udders in several dairies where the machines had been in operation for several months (in one case over three years), and no ill effects were discovered.

Nervous cows.—On two or three occasions it was observed that when strangers came into the barn during milking time a cow would appear frightened and refuse to give down all of her milk. This occurred with cows being milked either by hand or by machine. When the machines are properly adjusted, cows of a nervous disposition do not seem to resent the method.

Kicking cows.—The writer, after visiting from time to time several herds where the machines were in operation and observing the machines working continuously in one large herd for a month, failed to

find any cows that could not be milked because of the "kicking" habit. Reports from dairymen who have had experience with the machines confirm this statement. It is therefore believed that the machines give less trouble with such animals than the hand method.

Hard milkers.—The hard milker and the cow with small teats are milked much more easily and quickly by machine than by hand, and with the installation of milking machines there will be less reason for disposing of such cows. With the hard milker it is simply a question of keeping the machine at work a little longer, and with the small-teated cow care must be taken to have the teat cups of the proper size, and the pulsations may also be a little more rapid.

Heifers.—The results already secured indicate that the milking machine is particularly well adapted to heifers. Since milking is an artificial process, heifers that have never been milked by hand, as a rule, become much more quickly reconciled to the machine than older animals which have been milked for years by hand. The latter often have their udders more or less distorted and drawn out of shape by the hand method and do not as readily adapt themselves to the machine method.

Cows that refuse to be milked with the machine.—Occasionally a cow for some reason refuses to give down either a part or all of her milk. This does not seem to be due to nervous temperament. It is possible that the change from hand to machine milking is too radical for these particular individuals and that they need more time to become accustomed to it. Such cows do not make any objection to the machines being attached to them, but simply stand quietly and allow the machines to pump away without yielding any milk. As the cows that give this trouble are very few in number, dairymen who install machines usually dispose of them. Frequently, however, cows that refuse to give their milk at first milk freely after a short time.

ADJUSTING THE MACHINES TO THE COWS.

Great care should be taken to see that the proper-sized teat cups are used for each cow. Cows with large teats require larger and longer cups. If the cup is too small the teat will wedge into it and not milk; if too large it will not milk properly nor stay on so well. It has been found that a cow requires slightly larger cups when fresh than she does when advanced in the period of lactation. When fresh the udder is distended and a very small portion of it projects into the teat cup. Later, the udder as well as the teats are softer and more limp and project farther into the cup. During the tests made with the machines a cow occasionally refused to give down her milk simply because the teat cups used were not of the proper size; after new ones were adjusted the cow milked out clean. This emphasizes the importance of having cows always take the same places in the barn and

using teat cups of the same size at each milking. Cows will then become accustomed to the cups and will milk clean.

PRACTICABILITY OF USING MACHINES FOR LARGE AND SMALL HERDS.

Naturally the large dairyman will be the first to adopt the cow milker for the reason that his equipment will cost him less per cow than the small dairyman. Again, the large dairyman has more at stake and has to depend entirely upon the hired men to do the work. If they fail him the work falls upon himself or perhaps upon a very limited number of helpers. With the installation of the milking machine the large dairyman is much more independent, and if necessary could milk a herd of 50 cows without assistance. This would be next to impossible without it. However, there seems to be no good reason why a dairyman with a herd of even 10 or 12 cows could not use a machine with profit. The power required could be secured at small cost, and the time saved could be used to advantage in working the team longer on the farm or in other ways.

HOW THE GENERAL INTRODUCTION OF THE MILKING MACHINE WOULD AFFECT THE DAIRY INDUSTRY.

The scarcity of milkers and the unreliability of many of them has had a tendency to keep many men from going into dairy farming. Some dairymen who have been in the business have been obliged to give it up for this reason. Great interest therefore centers around the milking machine, especially where the above difficulty exists. With the introduction of the milking machine only about one-half the labor will be required to milk the cows, and it is believed that the labor employed will be of a higher class than heretofore and will also command higher wages. It is believed also that the advent of the milking machine will have a tendency among farmers who now have small dairies to enlarge their plants and to make dairying their chief business. The trouble has been in the past that too many farmers have made dairying secondary to other work, and when anything had to be neglected it was always the dairy. For this reason the profits from their dairies have been small. Where the milking machines have been introduced they have influenced dairymen to clean up their barns and take more pride in their work. This naturally will result in the production of cleaner milk and perhaps in some cases in better prices. Any new apparatus which has a tendency to improve dairy conditions should be welcomed by the industry.

SUGGESTIONS FOR IMPROVEMENTS.

Improvements will doubtless be made in this milking machine from time to time. At present two cows are milked in the same can, thus making it impossible to secure the weight of the milk from single

cows. A great deal of importance is now being placed upon records of individual cows in order to determine whether they are giving a profit to their owner, and this is a movement in the right direction. If individual cans were provided for the cows, accurate records could be secured for each animal. The difficulty of making machines for individual cows is not insurmountable; in fact a few machines have already been built which keep the milk from the two cows separate.

Another improvement that it is believed would add much to the practicability of the machine is a teat cup that could readily be adjusted to teats of any size or shape. At present cups of different sizes are used to meet the requirements of different animals. Some improvements in this direction are already in progress.

OBJECTIONS AND DIFFICULTIES.

As attention has been called to the advantages to be secured by the use of milking machines, it is proper to point out some of the objections and possible difficulties.

Initial outlay.—The considerable outlay in the beginning will prove a serious obstacle to dairymen of limited means; and, even with those who are financially able to make the investment, it will have a tendency to deter dairymen from the installation of machines until their practical utility has been fully demonstrated.

Careless or improper use.—As already suggested, the machines may be improperly or carelessly used. The operator may fail to select and use teat cups which fit, etc.

Life of the machine.—The machine or some of its parts may prove short-lived, thus causing expense and trouble.

Troubles with the engine.—In case a steam, gasoline, or gas engine is used (as will usually be the case), it will be necessary to employ some one who has sufficient knowledge and experience to run the engine. To do otherwise is to court disaster. Even with such a man, trouble with the engine may occur any day. Besides, the use of an engine in or near the barn involves danger of fire, and makes extra precautions necessary to avoid invalidation of fire insurance on the building.

Stoppages and breakdowns.—In the operation of any kind of machinery there is always danger that some part will break down or get out of order. With most machinery this is not a very serious obstacle, since the work to be done can await repairs. But milking is work that can not be postponed. Attention has been called to the independence of the dairyman who milks with machines as compared with the one who must depend on hired help to milk his cows by hand, inasmuch as the latter may find himself short of help at any time. The situation, however, is reversed when the engine or some other vital part of the equipment breaks down or gets seriously out of order. If

this occurs at or during milking time (as is likely), the dairyman who has installed machines, with 40 or more cows to milk, will find it very difficult, if not impossible, to bring in milkers enough to do the work by hand; and the difficulty will be aggravated if he loses time in unsuccessful attempts to repair the machinery.

Cleaning and care of the machines.—As this matter properly belongs in the second part of this bulletin, it need only be mentioned here as one of the difficulties which will demand the most serious attention of the dairyman who may attempt the use of milking machines.

NEED FOR FURTHER INVESTIGATIONS.

It is believed that the present investigations have yielded much valuable data, but they have been too limited in scope and time to justify final positive conclusions, even if the results had been uniform in their indications. The fact that they were not entirely so emphasizes the need for further investigation.

Unsettled questions.—Just when and how milk is formed in the udder of the cow, and the influences favorable or unfavorable to its formation, are subjects which are not well understood. Whether a purely mechanical device attached to the cow's teats to withdraw the milk from her udder will stimulate and favorably influence the formation of milk as well as the hands of the living milker must be considered an unsettled question.

Yield of milk.—In the matter of yield, experiment No. 1 gave a result slightly in favor of the machine, while experiment No. 2 gave a result slightly unfavorable to it. But it must be conceded that these experiments were too limited to settle definitely the question of yield even for short periods, while the effect of the continuous use of machines during full lactation periods was, of course, not tested at all.

Composition of the milk.—The composition of the milk is a matter of as great importance as the yield, and the effect on composition, of the means and methods employed in milking, is a part of the unsettled problem enunciated above. In experiment No. 1 the composition of the milk was, unfortunately, not tested. In experiment No. 2 the milk drawn by hand showed a considerably higher percentage of butter fat than that drawn by machines. It would of course be premature to conclude from this single test that machine milking will have an unfavorable influence on composition of the milk, but the need for more exhaustive investigation is certainly apparent.

Consideration such as the foregoing will naturally cause practical dairymen to hesitate regarding the installation of milking machinery until further careful experimentation yields fuller information and justifies more positive conclusions.

RESULTS OF EXPERIENCE WITH MILKING MACHINES AS REPORTED BY DAIRYMEN.

In order to have an expression of opinion direct from the dairymen regarding the use of cow milkers, a number of questions were sent to all dairymen who were known to have used machines for any length of time.

All of the 11 dairymen who reported said the effect of the machines upon the teats and udder of the cows was favorable; likewise the effect upon hard milkers, nervous cows, and kickers.

Nine reported that heifers adapted themselves readily to the machines; 1 stated that heifers took to them more readily than old cows, and 1 reported no experience. Of the five instances where 1 man handled 2 machines, the average number of cows milked was 23 and the average time required to milk them was 47 minutes, or practically 2 minutes per cow. In the one instance where 1 man handled 3 machines he milked 30 cows in 60 minutes. In the case where 2 men handled 4 machines 27 cows were milked in 40 minutes. In the two instances where 2 men handled 5 machines they milked an average of 52½ cows in 68½ minutes. Where 2 men handled 6 machines the time required was 1 minute per cow. Again where 3 men and boys were just learning they milked 30 cows in 55 to 75 minutes.

Some of the advantages of the machines reported were less help, less time required, and more and cleaner milk. One dairyman reported the cost to be a disadvantage, and another considered it a disadvantage to run the gasoline engine in winter.

From 1 to 4 cows in the different herds were reported as refusing to give their milk with the machine. Some reported having this trouble at first but said that later it disappeared.

Eight dairymen out of 11 did not think it necessary to strip the cows after using the machine, 2 thought it advantageous, and 1 simply stated that there was very little milk left after using the machines.

Six dairymen stated that they found little difference in the amount of milk produced, whether the cows were milked by hand or machine; 4 thought the machines increased the flow, and 1 stated that the effect of the machines on production was good.

All of the dairymen reported machine milking to be superior to hand milking.

ADDENDUM.

Since the experiments described in this bulletin were conducted (August, 1905), the condition of the milking-machine industry has greatly changed. Certain improvements have been made. For example, the milk ports thru the pulsator have been enlarged; a filter between the pail and the stanchion has been introduced, greatly reducing the number of bacteria; and the surging of the milk in the tubes has been prevented. The sanitary features have also been improved. Over a thousand of the machines are now reported to be in use.

II.—BACTERIOLOGICAL STUDIES OF A MILKING MACHINE.

By W. A. Stocking, Jr., M. S. A.,

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PRODUCTION OF SANITARY MILK.

At the present time there is a greater demand for milk which has been produced and cared for under such sanitary conditions as to insure its reaching the consumer in a pure, wholesome condition than for any other dairy product. In order to supply this demand the milk must reach the consumer in as nearly as possible the condition in which it leaves the udder of the healthy cow. One of the great difficulties in the way of supplying consumers with such a grade of milk lies in the dirt and the bacterial contamination which it receives before leaving the farm. As our knowledge of the laws of sanitation and the importance of pure foods becomes more widely disseminated among milk users this demand for a cleaner and more wholesome grade of milk will steadily increase. One of the greatest problems for the milk producer to solve is, therefore, that of producing such a grade of milk. A few dairymen are now producing a high grade of milk under such sanitary conditions as reduce the dirt and bacterial contamination to a minimum. For this purpose covered milk pails are commonly used, and great care is taken that the cows, the stables, the utensils, and the milkers shall be kept as clean as possible. All this extra care and labor is costly, and the milk thus produced demands a price considerably above the ordinary market price. This grade of milk fills a limited demand for those who can afford to pay the considerably increased price, but the problem of the milk supply for our cities will not be solved until the general consumer can be supplied with pure, clean milk at a reasonable price.

While the exercise of this increased care and the use of the covered pail reduce the chance for external contamination very materially and greatly improve the quality of the milk, the ideal condition would be to draw the milk directly from the udder into a closed receptacle without any chance for external contamination. This idea has stimulated in no small degree the inventors of the various styles of milking machines which have been developed during the last few years.

While it has been possible with some of these machines to draw the milk thru closed tubes directly from the udder into a closed receptacle, none of them have thus far proved satisfactory in all respects. If a machine could be devised which would be satisfactory in its effect upon the cow and upon the yield of milk, and which can be cleaned with reasonable ease and at the same time all contact of the milk with the surroundings could be prevented, it would go far toward solving the problem of providing the public with clean, wholesome milk.

EXPERIMENTS DESIGNED TO TEST THE SANITARY CHARACTER OF MACHINE-DRAWN MILK.

In planning this experimental work the writer had three main objects in view: (1) To determine the germ content of machine-drawn milk in comparison with that drawn by hand; (2) to test the efficiency of the machine in reducing the germ content to the minimum, and thus to determine its value in the production of "sanitary" milk; and (3) to determine the amount of care necessary to keep the machines in a sterile condition.

Two farms were chosen for this work; one, a dairy where the sanitary conditions were about the average existing in dairy barns, and the other representing a higher class of dairy barns in which sanitary milk might be produced.

EXPERIMENTS AT FARM NO. 1.

The first barn selected for this series of experiments is believed to represent about the average sanitary conditions of dairy barns in the principal dairy sections of the country. As may be seen by referring to the illustration (pl. 4, fig. 2), the barn itself was in good condition. The feeding alley, mangers, and drop were all of cement, while the stable floor on which the cows stood was of plank. The stable had been whitewashed and was fairly clean, but no special care was exercised each day in cleaning either the stable or cows nor in handling the milk.

METHOD OF EXPERIMENT.

In order to eliminate the difference due to the germ content of individual udders and give greater practical value to the work, two lots of 10 cows each were used in this series of tests. One of these lots was milked by machine and the other by hand. Samples from the mixt milk of each lot of 10 cows were taken as soon as the milking was completed and were carried to the laboratory. Owing to circumstances it was impossible to plate samples at night. The evening samples were therefore placed on ice until the following morning. The morning samples were also placed on ice as soon as obtained and plated after they were thoroly chilled. It is of course possible that there may have been some slight increase in numbers in the samples

of evening's milk before they were plated. It is probable, however, that there was normally no appreciable increase but rather a decrease in total numbers, due to the natural dropping out of certain species in accordance with the so-called "germicidal property" of milk. In either case the value of the results is not affected, since the hand-drawn and machine-drawn samples were treated alike in every case, and it is the comparison of these which is of value. In order to determine the numbers of bacteria existing in the milk, plate cultures were made in litmus sugar gelatin.

In plating any sample of milk it is of course a problem to know just what dilution to use in order to obtain the proper number of colonies in the culture plate. In order to be sure of getting satisfactory results two or three different dilutions were used in plating the milk, duplicate plates being made from each dilution. In most experiments all the plates developed with satisfactory numbers and the average of all was taken as representing the number of bacteria present in the milk, so that the figures given in this report represent the averages from the four or six plates made by the two or three dilutions from the same sample of milk. As soon as the plate cultures were made they were placed in an incubator in which a constant temperature of 70° F. was maintained. Here the cultures were allowed to develop for five days, at the end of which time they were studied for the following points:

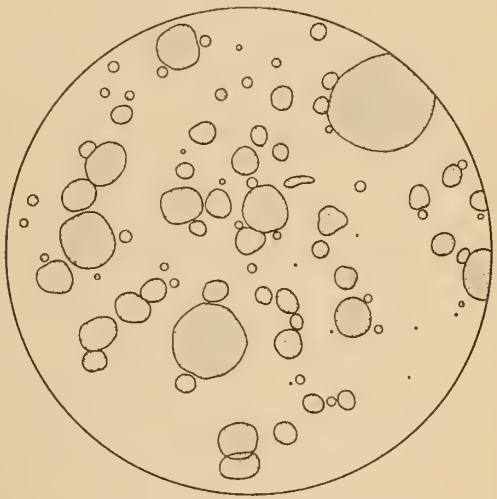

FIG. 1.—Bacteria in atmosphere of barn at farm No. 1. Drawing from photograph of gelatin plate exposed for five seconds in stable at milking time, showing the atmosphere to be well filled with bacteria and molds.

1. The total number of bacteria.
2. The number of acid-producing bacteria.
3. The number of liquefying or enzyme-producing bacteria.

The total number of bacteria indicates the amount of the contamination the milk has received. The number of acid-producing organisms was determined separately from the others because of their importance in connection with the keeping properties of the milk. The group of liquefying organisms includes those species which gain access to the milk thru filth and tend to produce putrefactive changes in it. It is this group especially which it is desirable to exclude from milk intended for human consumption, since it is believed that

members of this group are associated with certain digestive troubles, especially in children. It was believed that a study of this group might show interesting comparisons between hand-drawn and machine-drawn milk. The comparative data upon the keeping quality of the different samples of milk were obtained by taking subsamples as soon as the milk reached the laboratory, one of these subsamples being kept at a constant temperature of 70° F. and the other placed in an ice chest where the temperature did not vary greatly from 50° F., or that which is commonly maintained in home refrigerators.

FIRST TREATMENT OF THE MILKING MACHINES.

As previously stated, one of the points which the writer wished to determine was the amount of care necessary for the proper cleansing of the machines after each milking. For this purpose the treatment which the machines received was varied from time to time during the period covered by the tests. The treatment which the machines received is used as a basis for grouping and tabulating the results, and the effect of the various methods used in washing the machines will be brought out in the succeeding tables.

In the first place, it was desired to determine the efficiency of the method already in operation on the farm for washing the machines. This method was as follows: After the morning milking the machines were washt in water to which had been added some sal soda or other washing powder. They were then rinsed by pumping hot water thru them. After the night milking they were simply rinsed with cold water. The machines were not taken apart. The germ content of the milk drawn with the machines treated in this way, in comparison with milk drawn by hand, is shown in Table 4.

TABLE 4.—*Comparison of results of hand and machine milking—machines washt after morning milking with water and sal soda, then rinsed with warm water; after night milking, simply rinsed with cold water—machines not taken apart.*

Date.	No. of experiment.	Time of milking.	Method of milking.	Number of bacteria per cubic centimeter of milk.			Hours to curdling at—	
				Total bacteria.	Acid bacteria.	Liquefying bacteria.	70° F.	50° F.
July 22	3	Morning	Machine	105,000	.....	.....	35	a 65
	4	.....do....	Hand	33,233	4,233	3,466	35	a 65
July 23	7	.....do....	Machine	(b)	.....	.....	32	a 41
	8	.....do....	Hand	169,200	145,400	16,425	28	a 41
July 24	11	.....do....	Machine	1,046,400	1,043,650	2,750	39	a 65
	12	.....do....	Hand	79,725	16,400	8,225	39	a 65
July 25	15	.....do....	Machine	812,100	811,400	700	49	104
	16	.....do....	Hand	353,150	350,750	1,150	49	104
July 26	23	Night	Machine	1,571,200	.....	.....	28	67
	24	.....do....	Hand	988,350	988,350	6,025	45	76
July 27	25	Morning	Machine	1,543,200	1,536,025	7,175	51	49
	26	.....do....	Hand	215,900	188,600	21,775	a 41	57
July 27	27	Night	Machine	9,417,600	9,417,400	200	60	74
	28	.....do....	Hand	4,179,200	4,107,900	52,600	a 54	53
July 28	31	Morning	Machine	1,131,200	1,122,275	8,925	37	50
	32	.....do....	Hand	128,300	15,600	9,950	37	49
Average.	.....	.....	Machine	2,790,100	2,786,150	3,950	41	64
			Hand	768,382	727,154	14,952	41	64

a Curdled at night; exact time not determined.
b Too numerous to count with the dilution used.

It will be noticed, in the column marked "Total bacteria," that the machine-drawn milk contained in every case decidedly larger numbers of bacteria than did the milk drawn by hand at the same milking. The numbers obtained in the hand-drawn milk are about what might be expected from the ordinary method of hand milking in a barn of this grade, but the numbers in the machine-drawn milk are very much higher than they should be in fresh milk. It will be noticed also, by the study of the column marked "Acid bacteria," that the bacteria in the machine-drawn milk were chiefly acid-producing organisms, in many cases as high as 99 per cent being such. This proportion of acid bacteria is much larger than would result from ordinary stable contamination, and indicates that the machines were not being properly cleaned and that they furnished a breeding place for the acid-producing species. This would result in the milk that was drawn thru these machines becoming heavily inoculated with acid organisms. It is most significant to note that in spite of the extremely high total number of bacteria in the machine-drawn milk the number of liquefying organisms is in nearly every case very much smaller than in the corresponding hand-drawn milk. When we remember that it is this group which contains putrefactive organisms which get into milk principally from stable filth, and that these organisms producing putrefactive fermentations in the milk are believed to cause serious digestive troubles with children, the significance of these figures is at once apparent. As a result of the machine-drawn milk being protected from external contamination the number of organisms of this group which gained access to the milk was very materially reduced. At the close of this period, after it was thoroly demonstrated that the care which the machines were receiving was not sufficient to keep them in a sterile condition and that they served as breeding places for bacteria, a different method of cleansing was adopted.

SECOND TREATMENT OF THE MACHINES.

All the rubber tubes and teat cups were taken apart. It was found that the long tubes contained considerable quantities of decaying milk, thus making them decidedly insanitary. In order to cleanse these they were run thru a clothes wringer twice in order to loosen and squeeze out any dirt that might be in them. All parts of the machine were then placed in a boiler and thoroly boiled. After the boiling the parts were placed in a weak brine solution, where they remained until milking time. Another series of tests was then made, during which time the machines received the following treatment: After each milking the machines had cold water pumped thru them immediately. They were then washed with hot water containing washing powder, rinsed in boiling water, and placed in brine until needed for the next milking. The results obtained from the tests

made while the machines received this treatment are given in Table 5, the first part showing the results from the morning milkings and the second part the results from the night milkings.

TABLE 5.—*Comparison of results of hand and machine milking—machines taken apart and cleaned; rinsed in cold water, then hot sal soda water, then in boiling water, and placed in brine till used; rinsed just before use.*

NIGHT MILKING.

Date.	No. of experiment.	Method of milking.	Number of bacteria per cubic centimeter of milk.			Hours to curdling at—	
			Total bacteria.	Acid bacteria.	Liquefying bacteria.	70° F.	50° F.
July 28	33	Machine	347,800	324,050	13,300	43	50
	34	Hand	420,750	382,250	31,500	32	39
July 29	41	Machine	39,500	10,000	9,000	a 30	a 30
	42	Hand				a 30	49
July 30	45	Machine	622,000	138,000	10,500	36	63
	46	Hand	1,036,000	128,000	16,500	36	a 54
August 2	65	Machine	30,500	18,333	1,041	42	a 102
	66	Hand	681,500	127,000	82,750	a 30	88
August 3	71	Machine	332,000	69,000	57,332	a 30	100
	72	Hand	633,500	500,500	31,375	a 30	93
August 4	77	Machine	223,750	135,750	10,625	a 30	76
	78	Hand	1,302,666	964,500	279,000	28	65
August 5	83	Machine	242,250	97,000	52,625	a 30	69
	84	Hand	582,500	355,500	99,500	a 30	68
August 6	89	Machine	781,500	160,750	74,125	41	91
	90	Hand	197,500	51,000	13,375	a 30	67
Average		Machine	327,412	119,110	27,818	35	73
		Hand	693,488	372,687	79,143	31	65
Percentage		Machine		36.4	8.5		
		Hand		53.7	11.4		

MORNING MILKING.

July 29	37	Machine	89,400	57,100	2,450	30	a 41
	38	Hand	113,700	67,300	2,800	27	37
August 3	67	Machine	19,000	6,625	375	a 41	113
	68	Hand	117,125	66,375	9,250	34	85
August 4	73	Machine	52,875	28,000	3,875	32	65
	74	Hand	84,500	39,250	7,125	38	76
August 5	79	Machine	215,750	82,750	36,125	37	
	80	Hand	300,500	191,250	36,375	29	
August 6	85	Machine	249,250	56,000	34,625	36	a 65
	86	Hand	558,000	341,500	106,250	36	a 65
August 7	91	Machine	295,500	256,000	13,750	32	78
	92	Hand	266,500	227,500	19,125	29	51
Average		Machine	153,629	81,079	15,200	35	72
		Hand	240,054	155,529	30,152	32	63
Percentage		Machine		52.8	9.9		
		Hand		64.8	12.6		

a Curdled at night—exact time not determined.

A comparison of the column marked "Total bacteria" in the above table with the corresponding column in Table 4 shows a very marked diminution in the bacteria found in the machine-drawn milk. While the average for the machine-drawn milk in Table 4 was in round numbers 2,790,000, the average in Table 5 was 327,400 for the night milking and 153,600 for the morning milking. At the same time that this decided falling off in the numbers of bacteria in the machine-drawn milk occurred, the bacteria in the hand-drawn milk in the night

samples, as shown in Table 5, was not materially smaller than in Table 4, while in the morning milk the numbers were decidedly smaller. These differences are no greater than would be expected in any series of bacterial tests taken under similar circumstances. In the morning's milk, as shown in Table 5, the numbers of bacteria were also decidedly smaller in the machine-drawn milk. The most important fact to be noted here is the changed relation existing between the bacteria in the machine-drawn and hand-drawn milk. As shown in Table 4, before the machines were cleaned the milk drawn thru them contained many times more bacteria than did the hand-drawn milk, while after the cleaning, and with the brine treatment, the machine-drawn milk contained approximately only one-half as many bacteria as were contained in the milk drawn by hand.

A study of the acid-forming organisms reveals the fact that it was in this group that the decrease in numbers took place. While in the machine-drawn milk, in Table 4, there was an average of over 99 per cent of acid-producing organisms, in Table 5 the percentage of these bacteria was 36.4 (night) and 52.8 (morning). This decrease in the acid-forming bacteria in the machine-drawn milk in this series of tests completely reversed the relation existing between the bacteria found in the machine-drawn and hand-drawn milk, as shown in Table 4. In this series of tests it will be noticed that in almost every case the machine-drawn milk contained decidedly smaller total numbers of bacteria than did the corresponding hand-drawn milk. The same relation exists in the acid organisms, the machine-drawn milk containing both a lower total number and a lower percentage of acid organisms than did the corresponding hand-drawn milk. The night's milk as shown in Table 5 contained an average of 36.4 per cent of acid organisms for the machine-drawn milk as against 53.7 per cent for the hand-drawn milk, and in the morning's milk these percentages were 52.8 for the machine-drawn and 64.8 for the hand-drawn milk. Essentially the same relation in regard to the liquefying organisms in the machine-drawn and hand-drawn milk is shown in Table 5 as was shown in Table 4. The average percentage

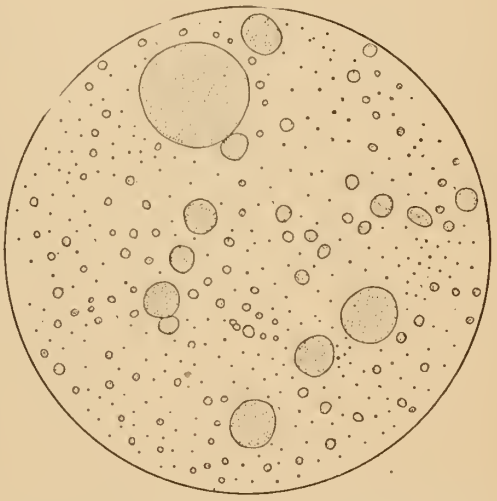

FIG. 2.—Bacteria in machine-drawn milk (426 colonies per plate) in experiment No. 37 (see Table 5).

of liquefiers in the machine-drawn milk of the night samples was 8.5, while it was 11.4 in the hand-drawn milk. In the morning's milk, that drawn by machine contained an average percentage of 9.9 and the hand-drawn 12.6 of liquefiers. The principal value of these two tables lies in the fact that they show such a marked decrease in the bacteria found in the machine-drawn milk, this decrease being the result of the greater care used in the washing of the machine.

THIRD TREATMENT OF THE MACHINES.

In spite of the greatly reduced number of bacteria obtained in the machine-drawn milk, the writer believed that the machines were not being properly sterilized. To test this, cultures were made by shaking sterile water in the rubber tubes after they had been washed as usual. The plate cultures made in this way showed that the short tubes and the ends of the long ones contained only small numbers of bacteria, but that the central part of the three long rubber tubes was still filled with bacteria, which were not being killed or removed by the method used for cleaning the machines.

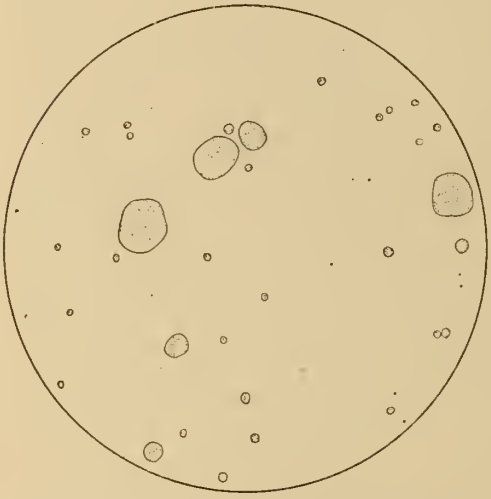

FIG. 3.—Bacteria in machine-drawn milk (43 colonies per plate) in experiment No. 101 (see Table 6).

A further test of this point was made in connection with experiments 77 and 78 by milking two cows with an entirely new machine. The milk thus obtained showed a germ content of 17,612 bacteria per cubic centimeter. At the same time the milk drawn into the machine which was in regular use contained 223,750 bacteria. This great difference in numbers of bacteria found in the milk drawn into the old and the new machines, together with the fact that such large numbers were found in the tubes used on the old machine, was considered definite proof that the daily care used in cleaning the machines was not sufficient to prevent their becoming breeding places for bacteria. Another change was therefore made in the treatment of the machines, and the results obtained are given in Table 6.

On these days the machines were rinsed with cold water as usual. They were then placed in water containing a small amount of powdered borax and boiled for at least one-half hour. The machines were then taken out and hung up in the open air until needed for use.

This treatment was given the machines on but two days. As shown in the table, the average for the machine-drawn milk was 28,562 and for the hand-drawn 48,125 bacteria per cubic centimeter. This is a much smaller number than had been previously obtained by either the machine or hand method, but the relative numbers are not materially different from those found in the previous series of experiments where the machines were soaked in brine. These results seem to indicate that the boiling in a weak borax solution and the soaking in the brine were about equally effective in freeing the machines of bacteria.

TABLE 6.—*Comparison of results of hand and machine milking—machines rinsed with cold water, boiled in water containing borax, then hung up in open air till used.*

Date.	No. of experiment.	Time of milking.	Method of milking.	Number of bacteria per cubic centimeter of milk.			Hours to curdling at—	
				Total bacteria.	Acid bacteria.	Liquefying bacteria.	70° F.	50° F.
August 7	95	Night	Machine	35,125	4,625	11,125	a30	86
	96	do	Hand	45,000	9,125	16,625	41	96
August 8	101	do	Machine	22,000	3,000	4,500	a54	111
	101A	do	do	7,875	0	0	.....	.....
	102	do	Hand	51,250	13,500	17,000	43	75
Averages			Machine	28,562	3,812	7,812	42	99
			Hand	48,125	11,312	16,812	42	86
Percentages			Machine	.....	13.4	27.4	.....	.....
			Hand	.....	23.5	35.0	.....	.....

a Curdled at night—exact time not determined.

FOURTH TREATMENT OF THE MACHINES.

On the night when samples 101 and 102 were taken, a third sample—marked in the table "101A"—was obtained by milking two cows into a machine, all parts of which had been placed in a box and subjected to live steam for 20 minutes. The results obtained in this way are very striking. The number of bacteria contained in the milk thus taken was 7,875, while the number from the other machines was 22,000 and in the milk drawn by hand 51,250.

FIFTH TREATMENT OF THE MACHINES.

At this point another change in the treatment of the machines was made. After being used at night they were rinsed with cold water, then washed with hot water, without the addition of any borax. The results obtained when the machines were thus treated are given in Table 7. After the morning milking the machines were rinsed with cold water as usual. They were then washt in hot water containing borax, after which all the rubber parts were placed in brine until needed for the evening milking. The results obtained from this treatment are shown in Table 8.

TABLE 7.—*Comparison of results of hand and machine milking—machines washt in cold water and then in hot sal soda water, no borax being used.*

Date.	No. of experiment.	Time of milking.	Method of milking.	Number of bacteria per cubic centimeter of milk.			Hours to curdling at—	
				Total bacteria.	Acid bacteria.	Liquefying bacteria.	70° F.	50° F.
August 8	97	Morning..	Machine	268,666	49,666	77,999	37	83
	98	.....do	Hand.....	296,250	122,000	103,375	28	63
August 9	103	.....do	Machine	5,875	500	625	38	96
	104	.....do	Hand.....	105,500	28,000	32,250	32	63
August 10	109	.....do	Machine	14,000	2,000	4,125	35	58
	110	.....do	Hand.....	102,250	5,875	19,375	30	a 41
August 11	115	.....do	Machine	72,375	5,125	6,625	37	a 65
	116	.....do	Hand.....	54,625	15,750	9,625	37	a 65
August 12	121	.....do	Machine	64,125	7,125	9,250	a 41	(b)
	122	.....do	Hand.....	944,000	326,000	92,000	26	a 41
August 13	127	.....do	Machine	84,375	4,000	6,375	35	(b)
	128	.....do	Hand.....	25,375	4,625	1,525	35	(b)
August 14	133	.....do	Machine	76,750	1,625	3,000	a 41	(b)
	134	.....do	Hand.....	42,625	2,375	250	35	(b)
Average			Machine.....	83,738	10,006	15,428	38	76
			Hand.....	224,375	78,089	36,914	32	58
Percentage			Machine.....		12.0	18.2		
			Hand.....		32.2	16.5		

a Curdled at night—exact time not determined.
b Not curdled by August 19.

In four of the experiments shown in this table the machine-drawn milk contained a much smaller number of bacteria than did the corresponding hand-drawn milk. In some of these cases the difference is very great, especially in experiments 103 and 104, and 109 and 110, where the numbers in the machine-drawn milk were small. In the other three experiments, however, the machine-drawn milk contained larger numbers of bacteria than did that drawn by hand. Still, the averages are decidedly in favor of the machine-drawn milk.

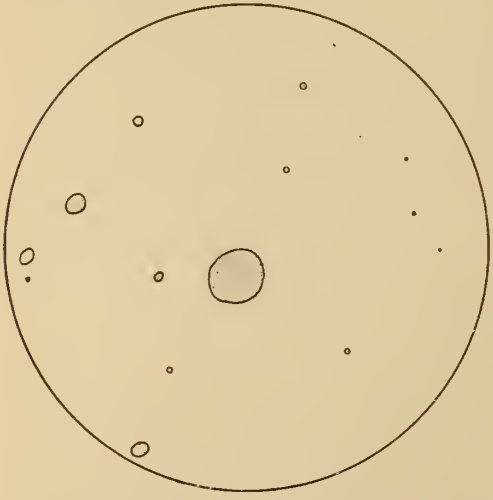

FIG. 4.—Bacteria in milk drawn by steam-sterilized machine (14 colonies per plate) in experiment No. 101A (see Table 6).

The results obtained from the night's milk where the machines were washt in borax water and soaked in brine will be found in Table 8.

TABLE 8.—*Comparison of results of hand and machine milking—machines washt in cold water, then in borax water, and all rubber parts placed in brine till used.*

Date.	No. of experiment.	Time of milking.	Method of milking.	Number of bacteria per cubic centimeter of milk.			Hours to curdling at—	
				Total bacteria.	Acid bacteria.	Liquefying bacteria.	70° F.	50° F.
August 9	107	Night	Machine	15,750	2,250	3,500	43	87
	107A	do	do	2,375	1,250	1,250	68	(b)
	108	do	Hand	115,500	40,500	34,625	38	71
August 10	113	do	Machine	31,750	13,000	7,375	50	101
	113A	do	do	8,750	750	1,375	a78	(b)
	114	do	Hand	56,625	7,125	22,250	38	73
August 11	119	do	Machine	49,625	6,500	15,875	a30	76
	119A	do	do	19,250	3,625	1,750	a54	(b)
	120	do	Hand	115,250	42,250	25,375	37	a54
August 12	125	do	Machine	17,750	1,625	2,250	45	(b)
	125A	do	do	13,500	500	2,666	45	(b)
	126	do	Hand	9,125	2,250	625	49	(b)
August 13	131	do	Machine	1,213,000	12,250	11,875	89	(b)
	132	do	Hand	49,875	7,000	0	(b)	(b)
August 14	137	do	Machine	27,625	1,875	1,000	(b)	(b)
	137A	do	do	21,000	250	1,625	(b)	(b)
	138	do	Hand	4,625	625	0	50	(b)
Average			Machine	225,917	6,250	8,125	42	88
			Machine A	12,975	1,275	1,733	61	(b)
			Hand	58,500	16,625	13,812	41	66
Percentage			Machine		2.7	3.6		
			Machine A		9.9	13.4		
			Hand		28.4	23.6		

a Curdled in night—exact time not determined. b Not curdled by August 19.

In a part of these experiments the results are very much in favor of the machines, while in the last three tests the comparison is in favor of the hand-drawn milk. This seems to be due to an unusually small number of bacteria in the hand-drawn milk rather than to any marked increase in the number in the machine-drawn milk, with the one exception of experiment 131. In this case it is evident that something decidedly wrong must have occurred to give the milk such an abnormally high germ content. If we leave this one experiment out of the averages we have for the machine-drawn milk an average of 28,500, instead of 225,900, and for the hand-drawn milk 60,225, instead of 58,500. This would give a showing greatly in favor of the machines, as is the case in the preceding tables.

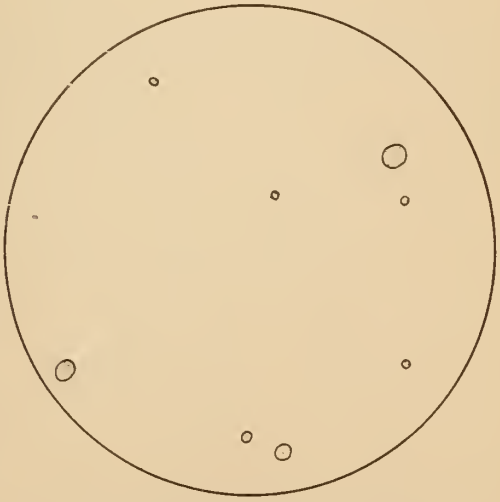

FIG. 5.—Bacteria in machine-drawn milk (8 colonies per plate) in experiment No. 103 (see Table 7).

SIXTH TREATMENT OF THE MACHINES.

In connection with the experiments shown in the preceding table, 2 cows were milked each night with a machine which had been subjected to live steam for 20 to 30 minutes. The results of the milk thus obtained are seen in the experiments marked "A" in the table. It will be seen that the numbers of bacteria in this milk are very much smaller than those obtained by the other machines, running as low as 2,375 bacteria per cubic centimeter in experiment 107A. These results seem to indicate that, even with the care that the regular machines were receiving, they still harbored relatively large numbers of bacteria which contaminated the milk drawn thru them. It will also be noticed that, even with the machine receiving the steam treatment, the germ content of the milk increased quite rapidly from day to day until it was about the same as in the regular machine-drawn milk. This is regarded as an indication that the steam treatment given was not sufficient to completely sterilize this machine, so that the bacteria gradually accumulated in the tubes. It was not possible to get any pressure in the box used for steaming this machine, and it is very probable that the temperature of the inside of the long rubber tubes did not reach that of the steam, and hence did not become sufficiently heated to kill the bacteria in them.

KEEPING QUALITIES OF THE MILK.

As stated at the beginning of this discussion, an attempt was made to determine the keeping qualities of the milk by taking two subsamples as soon as the milk reached the laboratory and keeping one of these at a constant temperature of 70° F. and the other at 50° F. During the day these samples were watched and the time at which they curdled was recorded. It was, of course, impossible to watch the samples during the night, so that in the case of many of them the exact time of curdling could not be determined. Where the samples curdled during the night the time of curdling was arbitrarily given as midnight, and all such results are indicated in the table.

The temperature of 70° F. was taken as representing fairly well the ordinary room temperature during the warm season, and that of 50° F. as representing the normal temperature of the refrigerator in the household.

The records of the time of curdling for the different samples are given in the various tables. It is not always easy to determine why a certain sample of milk should curdle when it does. In general, normal milk becomes sour and curdles in proportion to the number of bacteria contained, but this relation is true only between wide limits. Not infrequently one sample containing twice the number of bacteria contained by another will remain uncurdled the longer

time. There are, therefore, marked irregularities when we attempt to harmonize the keeping quality with the germ content. However, taking a series of samples containing a high germ content and comparing with another series with a comparatively low germ content, it will be found that there is an inverse relation existing between the germ content and the keeping quality. Frequently the species of organisms which the milk contains has more to do with determining its keeping quality than does the actual number of bacteria which may be in the milk. This fact accounts for many of the apparent discrepancies between the germ content and the keeping quality. While the results given in the preceding tables show many irregularities, yet they are of considerable interest, and in the long run are of value as an indication of the keeping quality of the different samples of milk.

SUMMARY OF EXPERIMENTS AT FARM NO. 1.

In Table 9 are given the averages for the germ content and keeping quality from the six preceding tables. While these averages are not of as much value as the results of the individual experiments, they give in a general way the relation existing between the machine-drawn and hand-drawn milk.

It will be noticed in this table that there is a difference in favor of the keeping quality of the machine-drawn milk, both in the samples kept at 70° F. and in those kept at 50° F., the greater difference in favor of the machine milk being shown in the samples which were kept at 50° F. One important fact which is shown in this table is the greatly increased keeping quality of the milk which was drawn into the steam-sterilized machine marked "A" in the table. These samples held at 70° F. kept on the average one-third longer than the average of the ordinary machine-drawn or hand-drawn milk, while those held at 50° F. had not curdled by August 19 when the test ended. This emphasizes the importance and indicates the possibilities of greatly increasing the keeping quality by thoroly sterilizing the machine.

TABLE 9.—*Summary of germ content and keeping quality of milk at farm No. 1.*

No. of table.	Number of experiments.	Method of milking.	Total number of bacteria found.	Hours to curdling at— 70° F.	50° F.
4	8	Machine	2,790,100	41	64
	8	Hand	768,382	41	64
5	8	Machine	327,412	35	73
	8	Hand	693,488	31	65
	6	Machine	153,629	35	72
	6	Hand	240,054	32	63
6	2	Machine	28,562	42	99
	2	Hand	48,125	42	86
7	7	Machine	83,738	38	76
	7	Hand	224,375	32	58
8	6	Machine	225,917	42	88
	5	Machine A	12,975	61	(a)
	6	Hand	58,500	41	66

a Not curdled by August 19.

EXPERIMENTS AT FARM NO. 2.

The conditions of cleanliness existing in this stable are considerably above the average (fig. 6.) From a sanitary standpoint this stable was not as well constructed as was the one at farm No. 1. The stable is entirely below ground on the west and north sides, but receives a good supply of light from the south and east. The feeding alley and mangers are made of cement, but the stable floor, the drop, and the main floor behind the cows are made of plank. While the construction of the stable itself is not especially suited to the production of clean milk, considerable care was taken to keep the stable and the cows as clean as possible. Considerably more than average care was exercised in the milking and the subsequent handling of the milk, so that this stable may properly represent a fairly sanitary dairy. It is not to be expected that the germ content of milk produced in such a stable could be kept as low as in a stable constructed on more approved sanitary plans, but the number of bacteria found in the hand-drawn milk, as given in the following tables, shows, however, that the sanitary conditions of the stable at milking time were excellent. The stable floor was always swept twenty minutes to one-half hour before milking was commenced, and just before milking, the udders were wiped with a damp cloth.

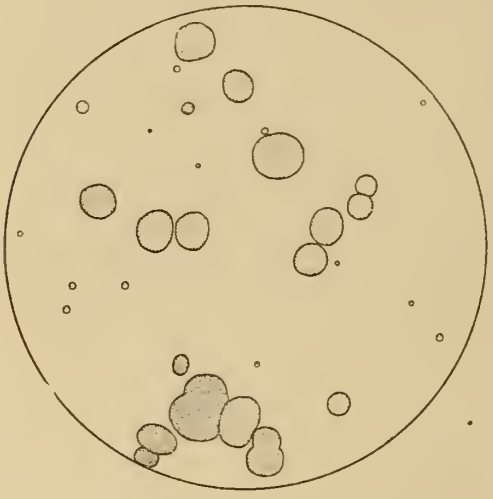

FIG. 6.—Bacteria in atmosphere of barn at farm No. 2. Drawing from photograph of gelatin plate exposed for twenty seconds in stable at milking time, showing the low germ content of the atmosphere, 34 colonies per plate.

METHOD OF EXPERIMENT.

In beginning the experiments in this dairy it was desirable, first, to ascertain the relative germ content existing in the machine-drawn and hand-drawn milk. For this purpose the herd was divided into two lots of 4 cows each. One of these groups was milked by the machine and the other by hand into an open pail in the ordinary way. As soon as the milking was completed, samples were taken from the mixt milk of each group of cows and these were carried to the laboratory for testing. The details of these experiments are the same as those already outlined in connection with the experiments at farm

No. 1. In this series of tests samples were taken at the night milking only and were placed on ice until the next morning, when the plate cultures were made. It is probable that the figures given in the tables are slightly lower than would have been obtained had the samples been plated immediately, since there is usually a dropping out of certain species during the first few hours after drawing the milk. In a few cases where the samples were plated at night and again the next morning this was shown to be true.

FIRST TREATMENT OF THE MACHINES.

At the outset it was desired to ascertain the efficiency of the milking machine with the treatment it was regularly receiving on the farm. Three days' tests were made without altering the treatment which the machines received and the results were compared with those obtained from the corresponding samples drawn by hand. The results of these tests are given in Table 10.

TABLE 10.—*Comparison of results of hand and machine milking—machines rinsed with cold water, washt with warm water containing sal soda, then rinsed with hot water.*

Date.	Number of experiments.	Method of milking.	Bacteria per cubic centimeter of milk.					Hours to curdling at—	
			Total bacteria.	Acid bacteria.	Per cent of acid bacteria.	Liquefying bacteria.	Per cent of liquefying bacteria.	70° F.	50° F.
July 21	2	Machine	69,130	1,513	2	683	1	62	110
	1	Hand	24,100	.....	.....	2,325	10	40	100
July 22	5	Machine	8,143	7,213	89	1,400	17	76	165
	6	Hand	1,900	492	26	100	5	76	147
July 23	9	Machine	441,600	439,000	99	1,850	0	52	97
	10	Hand	2,200	570	26	150	7	52	86
Averages	.....	Machine	172,958	149,242	.....	1,311	.....	63	124
	.....	Hand	9,400	531	.....	858	.....	56	111

During this period the machines were treated as follows: After milking they were rinsed by pumping cold water thru them. This was followed by warm water containing some washing powder, commonly sal soda. They were then rinsed with clean hot water and hung up in the air until needed for use at the next milking. A glance at the "Total bacteria" column in the table shows the same relation existing between the bacteria found in the hand-drawn and machine-drawn milk as was found in the experiments at farm No. 1. The number of bacteria in the machine-drawn milk was decidedly higher than in the corresponding hand-drawn milk in each experiment, the average for the three samples of machine-drawn milk being 172,958 bacteria per cubic centimeter, while the average for the hand-drawn milk is 9,400. It will also be seen that the organisms in the machine-drawn milk were largely acid-producing species. This also corresponds to the conditions

found at farm No. 1. It is evident that the milk became contaminated with large numbers of acid-producing organisms while passing thru the machines. These results seem to prove beyond question that the care which the machines were regularly receiving was not sufficient to keep the tubes in a sterile condition and they had therefore become breeding places for bacteria, which were washt into the milk when the machines were used.

SECOND TREATMENT OF THE MACHINES.

At this point a slight change was made in the method of treating the machines, and the figures given in Table 11 show the results of two days' tests with the machines thus treated.

TABLE 11.—*Comparison of results of hand and machine milking—treatment of machine the same as indicated for Table 10, except that it was scalded just before use by pumping boiling water thru it.*

Date.	No. of experiment.	Method of milking.	Bacteria per cubic centimeter of milk.					Hours to curdling at—	
			Total bacteria.	Acid bacteria.	Per cent of acid bacteria.	Liquefying bacteria.	Per cent of liquefying bacteria.	70° F.	50° F.
July 24	[a] 13	Machine	226,700	8,883	3	2,287	1	76	130
	14	Hand	11,850	2,600	22	250	2	[b] 54	[b] 102
July 26	21	Machine	12,000	4,988	42	487	4	97	171
	22	Hand	1,100	475	43	112	10	64	171
Average		Machine	119,350	6,935		1,387		87	151
		Hand	6,475	1,537		181		59	137

[a] Udders not washt. [b] Curdled at night—exact time not determined.

The machines were washt as previously described, but they were given an additional scalding just before being used by pumping boiling water thru them. It was hoped that this might dislodge and wash out any bacteria which might have accumulated in the tubes during the day, thus reducing the germ content of the milk. This additional scalding, however, apparently had little effect upon the condition of the tubes, since the numbers of bacteria were not materially decreased, as will be seen by a study of Table 11. Both the total number and the number of acid-producing organisms and also the liquefying bacteria continued to be much more numerous in the machine-drawn milk than in that drawn by hand.

It will be noted that in experiment 13 the udders were not wiped with a damp cloth previous to milking. This fact, no doubt, at least partially accounts for the high numbers of bacteria found in this lot of milk.

THIRD TREATMENT OF THE MACHINES.

After being washt as previously described, the rubber tubes and teat cups were placed in water and boiled for three-quarters of an hour. They were then hung up in the open air until needed for the next milking. Just before using they were rinsed as in the previous experiments by having boiling water pumped thru them. Table 12 gives the results of four tests taken with the machines thus treated.

TABLE 12.—*Comparison of results of hand and machine milking—machines rinsed with cold water and washt with sal soda, then boiled for three-quarters of an hour and rinsed with boiling water just before use.*

Date.	No. of experiment.	Method of milking.	Bacteria per cubic centimeter of milk.					Hours to curdling at—	
			Total bacteria.	Acid bacteria.	Per cent of acid bacteria.	Liquefying bacteria.	Per cent of liquefying bacteria.	70° F.	50° F.
July 27	29	Machine	18,737	3,025	16	612	3	91	74
	30	Hand	781	125	10	137	18	a126	a150
July 28	35	Machine	5,612	50	1	100	2	144	a54
	36	Hand	6,537	462	7	50	1	a54	a126
July 29	39	Machine	85,700	82,950	97	1,750	2	a78	134
	40	Hand	7,175	75	1	2,200	3	50	87
July 30	47	Machine						a54	a102
	48	Hand	10,350	3,050	30	1,000	9	52	171
Average		Machine	36,683	28,675		1,231		91	91
		Hand	6,211	985		847		71	133

a Curdled at night—exact time not determined.

This increased treatment of the machine apparently was not sufficient to greatly change the quality of the machine-drawn milk. However, in experiment 35 the number of bacteria in the machine-drawn milk was somewhat less than in the corresponding hand-drawn sample. It should be borne in mind that the numbers of bacteria obtained by the hand milking are extremely low for milk drawn into an ordinary open pail. These low numbers of bacteria found in the hand-drawn milk emphasize the fact that the atmosphere in the stable was relatively free from organisms, and that considerable care was exercised in the drawing and handling of the milk. The man who did the milking was unusually careful in all his operations. In experiment 39 the rubber tube connecting the pulsator with the stanchion cock was not boiled with the other tubes, and it is probable that this furnished the source of contamination and explains the very high number of bacteria in this lot of milk. In order to determine whether the rubber tubes were responsible for the larger numbers of bacteria in the machine-drawn milk a new set of tubes was used in experiments 63 and 69. These new tubes were washt and then scalded, together with the rest of the machine, just before using. This resulted in a smaller number of bacteria from the machine-drawn milk than had been previously obtained.

TABLE 13.—*Comparison of results of hand and machine milking—new tubes and teat cups used, and machines washt as usual and scalded just before using.*

Date.	Number of experiment.	Method of milking.	Bacteria per cubic centimeter of milk.					Hours to curdling at—	
			Total bacteria.	Acid bacteria.	Per cent of acid bacteria.	Liquefying bacteria.	Per cent of liquefying bacteria.	70° F.	50° F.
August 2	63	Machine	3,625	162	4	87	2	86	[a] 126
	64	Hand	650	275	42	25	4	161	206
August 3	69	Machine	[b] 1,637	925	58	25	1	50	116
	70	Hand	1,344	150	12	144	11	[a] 102	[a] 126
Averages		Machine	2,631	543	.....	55	.....	68	121
		Hand	997	212	.....	84	.....	132	166

[a] Curdled at night—exact time not determined. [b] Two jets of foremilk removed.

The results of these tests as shown in Table 13 would make a very good showing for the machine were it not for the fact that the numbers in the hand-drawn milk were so extremely low. However, it ought to be possible to obtain milk by means of the machine which would contain a lower germ content than hand-drawn milk under the same conditions provided the parts of the machine thru which the milk past were sterile at the outset, since the milk drawn by means of the machine is entirely shut off from external contamination. It ought to be possible to obtain the milk in the pail with practically nothing but the bacteria which exist in the udder. This manifestly was not the case with the trials made thus far and it was evident that still greater care was necessary in order to completely sterilize the machines.

In order to determine the real condition of the inside of the tubes a test was made at this point to find out whether or not the inside of the rubber tubes was being sterilized by the treatment given them. A small quantity of sterilized water was run into the central part of the long rubber tubes and rinsed back and forth. This was then poured out and a drop of this water inoculated into a gelatin plate. This resulted in the development of 1,728 colonies of bacteria as the germ content of a single drop of the water used for rinsing the tube. This showed beyond a doubt that the inside of the tubes was not being properly cleansed and sterilized by the treatment thus far used and that greater care was necessary in order to overcome this trouble.

FOURTH TREATMENT OF THE MACHINES.

The writer desired especially to test the efficiency of the machine for the production of sanitary milk, or milk containing a minimum germ content. It was therefore decided to take still more vigorous means for cleansing and sterilizing the machines. To do this, in addition to the treatment usually given, the tubes were boiled for three-quarters of an hour in water containing a small quantity of powdered borax. They were then thoroly rinsed with boiling water to

remove any traces of borax which might be in the tubes. A small amount of borax was also added to the water used for wiping off the udders. In addition to these precautions a small amount of foremilk was also drawn before attaching the machine to the cows, and the pail was carried out of the stable before the cover was removed. This treatment proved to be more effective than any previously given, as will be seen by a study of Table 14.

TABLE 14.—*Comparison of results of hand and machine milking—machines rinsed with cold water, washt with warm water containing sal soda, boiled three-quarters of an hour in water with borax, and scalded just before use; udders wiped with borax water.*

Date.	No. of experiment.	Method of milking.	Bacteria per cubic centimeter of milk.					Hours to curdling at—	
			Total bacteria.	Acid bacteria.	Per cent of acid bacteria.	Liquefying bacteria.	Per cent of liquefying bacteria.	70° F.	50° F.
August 4	75	Machine	462	.....	.....	.....	.....	62	115
	76	Hand	1,550	225	15	419	28	49	139
August 5	81	Machine	400	12	3	25	6	123	(a)
	82	Hand	881	81	9	0	0	b 54	(a)
August 6	87	Machine	612	112	18	37	6	b 78	124
	88	Hand	1,300	75	6	80	6	48	100
Averages	.....	Machine	506	62	.....	31	.....	88	120
	.....	Hand	1,090	78	.....	40	.....	50	120

a Not curdled by August 19. b Curdled at night—exact time not determined.

It will be noticed in this table that the machine-drawn milk contained in each case much smaller numbers of bacteria than did the corresponding hand-drawn milk. These numbers compare very favorably with the germ content of the best grades of "sanitary" or "clinical" milk which are now placed upon the market. In fact these numbers are below the germ content of much of such milk. The results of these tests are sufficient to prove that the germ content of milk can be reduced to a very low figure by the use of the machine when properly sterilized. While the boiling in borax water was apparently an effective treatment, attention should be called to the danger of using this or other antiseptics to rid the rubber tubes and teat cups of bacteria. A very thoro rinsing of the tubes is necessary in order to remove all traces of the antiseptic so that none of it can be taken up by the milk as it passes thru the machine. If the antiseptic were left in the tubes it would be the same in effect as treating the milk with a preservative—a practise that is considered very objectionable. There was also some question in regard to the effect of the boiling upon the life of the rubber tubing, and it was some work to boil the machines in this way each day. For these reasons it was thought desirable to find a simpler way of sterilizing the machines and one which would not have an injurious effect upon the rubber.

FIFTH TREATMENT OF THE MACHINES.

Common salt is a good germicide, and it also has a hardening and preservative effect upon the rubber. It was therefore thought that possibly a brine solution might be used for sterilizing the rubber tubes instead of boiling them in borax water. To test this the machines were washt as usual, after which all the rubber parts were placed in a moderately strong brine solution, where they remained until needed for the next milking. Before being used they were thoroly rinsed by having boiling water pumped thru them. Table 15 gives the results of the tests made with the machines thus treated.

TABLE 15.—*Comparison of results of hand and machine milking—machines being washt as usual, the rubber parts then placed in brine till needed, and scalded just before use.*

Date.	No. of experiment.	Method of milking.	Bacteria per cubic centimeter of milk.					Hours to curdling at—	
			Total bacteria.	Acid bacteria.	Per cent of acid bacteria.	Liquefying bacteria.	Per cent of liquefying bacteria.	70° F.	50° F.
August 7	93	Machine	6,450	475	7	625	10	52	100
	94	Hand	4,075	562	14	363	9	[a]54	[a]102
August 8	99	Machine	400	112	28	100	25	48	109
	100	Hand	600	100	16	0	0	68	121
August 9	105	Machine	483	100	21	33	7	101	[b]
	106	Hand	18,750	1,350	7	1,449	8	[a]78	[b]
Averages		Machine	2,444	229	.....	253	.....	67	105
		Hand	11,712	1,006	.....	604	.....	67	112

[a] Curdled in night—exact time not determined. [b] Not curdled August 19.

It will be noticed that in experiment 93 the number of bacteria was decidedly higher than in the preceding tests given in Tables 13 and 14, while in experiments 99 and 105 they were as low as when the machine was treated with borax. Probably the higher number in experiment 93 was due to the fact that only part of the rubber tubes were treated with the brine solution, while on other days all the rubber parts were placed in the brine. It would seem from the results of these tests that the brine treatment is as effective as the boiling in borax water and is at the same time much simpler.

SIXTH TREATMENT OF THE MACHINES.

The usual method for sterilizing dairy utensils is by steam. This is entirely satisfactory with ordinary dairy utensils, but steam is known to have an injurious effect upon rubber, for which reason steam sterilizing was not generally used in this series of experiments; but at this point it was deemed desirable to compare the efficiency of steam sterilizing with the treatments previously given, in order to determine whether or not it was possible to reduce still further the germ content of the machine-drawn milk. To accomplish this a large wooden box

was fitted up to serve as a steam sterilizer. After the machine had been washt as usual, it was placed in this box and subjected to live steam for 30 minutes. Table 16 gives the results of this series of tests.

TABLE 16.—*Comparison of results of hand and machine milking—machines washt as usual and sterilized in steam for thirty minutes.*

Date.	Number of experiment.	Method of milking.	Bacteria per cubic centimeter of milk.					Hours to curdling at—	
			Total bacteria.	Acid bacteria.	Per cent of acid bacteria.	Liquefying bacteria.	Per cent of liquefying bacteria.	70° F.	50° F.
August 10	111	Machine	560	37	7	0	.....	77	(a)
	112	Hand	400	112	28	75	19	158	(a)
August 11	117	Machine	1,962	337	18	75	4	69	(a)
	118	Hand	1,762	375	22	287	17	b 30	60
August 12	123	Machine	1,087	137	14	75	7	45	(a)
	124	Hand	850	100	12	112	13	49	(a)
August 13	129	Machine	9,887	225	2	375	4	(a)	(a)
	130	Hand	5,540	860	10	250	5	b 78	(a)
August 14	135	Machine	3,750	387	10	162	4	b 54	(a)
	136	Hand	1,337	362	28	275	21	(a)	(a)
Averages	.....	Machine	3,449	225	.....	137	.....	64	.....
	.....	Hand	1,978	362	.....	200	.....	79	.....

a Not curdled August 19. b Curdled at night—exact time not determined.

It will be noticed that in each test the machine-drawn milk contained larger numbers of bacteria than did the corresponding hand-drawn sample. It was impossible, with the equipment used, to get any pressure in the steam chest, hence the temperature did not quite reach the boiling point (212° F.). Under these conditions it is probable that the inside of the rubber tubes did not become heated to the temperature of the steam, and they, therefore, were not sterilized during the thirty minutes that they were subjected to the steam treatment. Probably a longer steaming might prove effective, but it is evident that the treatment here given was not sufficient to completely sterilize the tubes. The rubber tubing did not appear to be seriously injured by the steam treatment during this series of tests, but it is quite probable that long-continued steam sterilizing would injure the rubber. This series of tests would at least indicate that it is necessary to subject the tubes to greater steam pressure or else use other germicides in order to completely sterilize the rubber tubing. At the close of this period one test was made by treating the machine in brine, as already described. The results of this test are shown in Table 17.

TABLE 17.—*Comparison of results of hand and machine milking—machines treated as indicated for Table 15.*

Date.	Number of experiment.	Method of milking.	Bacteria per cubic centimeter of milk.					Hours to curdling at—	
			Total bacteria.	Acid bacteria.	Per cent of acid bacteria.	Liquefying bacteria.	Per cent of liquefying bacteria.	70° F.	50° F.
August 15	141	Machine	13,675	2,463	18	1,056	8	.....	.....
	142	Hand	2,100	763	36	493	23	62	.....

KEEPING QUALITIES OF THE MILK.

The discussion of the keeping qualities of the milk given in connection with the experiments at farm No. 1 will in general apply with equal force to the results obtained at farm No. 2. Practically the same results were obtained in both cases. In the majority of instances the difference in keeping quality is in favor of the machine-drawn milk, both at 70° and 50° F. This difference is especially noticeable in Table 14, where the germ content of the machine-drawn milk averaged the smallest. With an average of 506 bacteria per cubic centimeter the milk kept on an average eighty-eight hours at 70° F., while the hand-drawn milk, with an average of 1,090 bacteria, kept an average of but fifty hours, making an average difference of thirty-eight hours in favor of the machine-drawn milk. This, at least, is an indication of the extent to which the keeping quality of the milk may be improved by the use of the machines, provided they are kept in a sterile condition and care is used in their manipulation.

SUMMARY OF RESULTS OF BACTERIOLOGICAL INVESTIGATIONS.

The results of the foregoing experiments seem to justify the following conclusions:

1. Unless sufficient care is used in cleaning the machines, decaying milk and bacteria accumulate in the rubber tubes and contaminate the milk as it passes thru them.

2. The few dairymen now using these machines are not exercising sufficient care in washing and sterilizing the machines to keep them in sanitary condition; their milk is therefore of poorer quality from the sanitary standpoint than that drawn by hand under the same stable conditions.

3. Good sanitary conditions in a stable may be completely counteracted by the insanitary condition of the milking machine.

4. When kept in fairly clean condition the machine-drawn milk contains decidedly smaller numbers of bacteria than the corresponding hand-drawn milk.

5. When the machines are not well cleaned both the number and percentage of acid-producing bacteria are higher than in the hand-drawn milk, but when they are fairly well cleaned both the total number and the percentage of these bacteria are decidedly lower than in the corresponding hand-drawn milk.

6. Both the total number and the percentage of liquefying bacteria found in the milk were in most cases greatly reduced by the use of the machines. This fact is of special significance in milk designed for direct consumption.

7. When properly cared for, drawing the milk by means of the machine increases its keeping quality.

8. Washing the machines with cold water and then with hot water containing sal soda is not sufficient to keep the rubber tubes clean. Under this treatment the inside of the tubes becomes coated with decaying milk, thus forming ideal conditions for the multiplication of various species of bacteria.

9. Scalding the machines by pumping boiling water thru them just before use had little or no effect in reducing germ content of the milk.

10. Boiling in clear water for three-quarters of an hour was not sufficient to keep the rubber tubes in a sterile condition.

11. Subjection to steam without pressure for thirty minutes was not sufficient to sterilize the rubber tubes.

12. Placing the rubber parts in brine for several hours after being washt reduced the germ content of the machine-drawn milk to about one-half that of the milk drawn by hand.

13. Boiling in water containing a small amount of powdered borax had about the same effect in reducing the bacterial content of the milk as did the brine treatment, but the use of borax is dangerous unless extreme care is exercised.

14. The machines may be very effective in the production of sanitary milk if they are properly cleaned and sterilized.

15. The results of these experiments indicate that the machines may be kept in such an insanitary condition that the keeping quality will not be improved, but may be seriously impaired. They also indicate that with properly cleaned and sterilized machines the keeping quality of the milk may be very materially improved.

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